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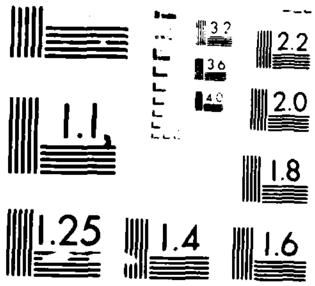

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AN EVALUATION OF ROTARY AIR STRIPPING FOR REMOVAL OF VOLATILE ORGANICS FROM GROUNDWATER

CHRIS DIETRICH, DIANNE TREICHLER, JOHN ARMSTRONG

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FEBRUARY 1987

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Rotary air stripping was researched and developed to remove volatile organic contaminants from groundwater. The Traverse Group, Inc., Ann Arbor MI, was contracted under a joint funding venture by the US Coast Guard and the US Air Force to evaluate feasibility of using rotary air stripping to treat water contaminated with benzene, toluene, xylenes, trichloroethylene, 1,2,dichloroethane, and tetrachloroethylene. A site of groundwater contamination at the US Coast Guard Station, Traverse City MI provided a readily available source of contaminated water for this work. A prototype rotary air stripper (RAS), manufactured specifically for this project, was installed onsite in Traverse City MI. The RAS (consisting of a packed bed 1.7 feet in diameter by 1.2 feet thick) was evaluated over a range of contaminant concentrations (63 to 19,000 ppb), liquid flow rates (50 to 120 gpm), air to water ratios (10:1 to 170:1 vol/vol), and rotor speeds (365 to 875 rpms). The effect of each parameter on removal efficiency was analyzed. Generally, removal efficiencies in excess of 99 percent were achieved for all contaminants (except 1,2-DCE) at an air-to-water ratio and rotor speed of 30:1 vol/vol and 435 rpms, respectively. (continued)

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efficiency increased with air-to-water ratio and rotor speed, but was not affected by contaminant concentrations. Preliminary calculations show the operating cost of the RAS is higher than a conventional countercurrent packed column (CCPC), but for a CCPC to achieve the same removal efficiency requires a much larger packed bed volume.

PREFACE

This report was prepared by the Traverse Group, Inc., of Ann Arbor MI 48105. This work was contracted under a joint venture by the US Air Force and the US Coast Guard, MIPR No FY8952-85-10019.

The report is an evaluation of a prototype rotary air stripper for removing five organic compounds from groundwater. The work was performed between October 1985 and September of 1986. The AFESC/RDVW Project Officer was Captain Richard A. Ashworth.

The success of this project is due in part to the dedication and hard work of Mr Bill Newman, TGI Environmental Chemist, and Ms Kathy Hill, TGI Data Processor. Special thanks goes to Commander John Sammons and Capt Randy Gross for their roles in facilitating the installation of the equipment and in initiating this research project.

Mention of trademarks and trade names of material and equipment does not constitute endorsement or recommendation for use by either the Air Force or US Coast Guard, nor can the report be used for advertising the product.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including Foreign Nationals.

This technical Report has been reviewed and is approved for publication.

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SECTION I

INTRODUCTION

A. OBJECTIVE

This report summarizes the field evaluation of a protoype Rotary Air Stripper (RAS) located at the United States Coast Guard Air Station Traverse City, Michigan. Objectives of the evaluation were as follows:

1. Determine removal efficiency of a rotary air-stripper for volatile organics.

2. Determine the cost efficiency of rotary air-stripping water contaminated with chlorinated and nonchlorinated hydrocarbons.

3. Evaluate operation and maintainance requirements for a rotary air-stripping facility.

B. BACKGROUND

To further develop groundwater cleanup technologies, the US Coast Guard and the US Air Force, jointly contracted with Glitsch Corp. to build a prototype RAS for evaluation at the USCG Air Station in Traverse City, Michigan. The Traverse Group, Inc. (TGI), of Ann Arbor, Michigan, had been contracted by the Coast Guard to manage the Groundwater cleanup project at the Traverse City Air Station in October of 1984. TGI was also tasked with the installation, experimentation, and evaluation of the RAS.

In 1980, volatile organic compounds were found in groundwaters of East Bay Township, Traverse City, Michigan. Investigations by the United States Geological Survey indicated that the US Coast Guard Air Station might be the source of the contamination (Reference 1). In 1985, a hydraulic fence of pumping wells was installed to effectively block the further migration of contaminated groundwaters from Coast Guard property. Pilot-scale granular activated carbon and air-stripping studies were conducted to evaluate treatment alternatives for the contaminated water. Both treatment alternatives were found to be effective and granular activated carbon was chosen, on a temporary basis. The hydraulic fence and carbon adsorption units were put into operation in April 1985.

After the migration of contaminated groundwaters was halted, analysis of more economical water treatment alternatives began. Air-stripping studies, such as those carried out at Wurtsmith Air Force Base, Michigan, showed air-stripping to be a cost-effective alternative to granular activated carbon adsorption. It was decided to set up an air-stripping system on the Coast Guard Base.

Commander John Sammons of the USCG and Dr. John Armstrong, of the Traverse Group, Inc., discovered a newly developed process for increasing mass transfer in chemical distillation systems while reviewing air-stripping technologies. The new process was developed by Mr. Colin Ramshaw of the Imperial Chemical Industries of Great Britain. Further research found that the Glitsch Corporation of Dallas, Texas, presently holds the world wide license for the process. The process uses a rotating packed bed to increase the acceleration or "g" force imparted on the liquid. By increasing the g force, a packing material with a higher specific surface area than conventional tower packing may be used. Thus, the effective mass transfer is increased.

C. APPROACH

The RAS achieved operational status in October of 1985. Experimental parameters to be analyzed were determined during preliminary operation of the treatment system. The air flow rate and rotor rotational velocity were determined to have the greatest effect on performance.

Two phases of experimentation were conducted on the RAS. The first phase determined operating conditions where removal efficiencies and treatment costs of the RAS were optimized. The second phase of experimentation, using the same operating conditions as the first phase, determined the treatability of a variety of different contaminants at varying concentrations.

SECTION II

ROTARY AIR-STRIPPING SYSTEM

A. ROTARY AIR-STRIPPING THEORY

Air-stripping is the process of contacting contaminated water with a clean air stream. In a closed system, hydrocarbons with low solubilities in water diffuse into air, eventually reaching equilibrium, according to Henry's Law. When a steady stream of air is passed by the water, the contaminants continuously diffuse into the air, never reaching equilibrium. In a system employing countercurrent air and water flow, the ever present concentration gradient steadily drives the removal process. The contaminants are effectively stripped from the water.

Before the development of rotary air-stripping, there were two primary means of conventional air-stripping, diffusive aeration, and countercurrent packed-column (CCPC) air-stripping. In diffusive aeration, a basin of contaminated water is sparged with air bubbles. This method of air-stripping produces limited contact between the water and the air, hence limiting stripping of the contaminants. Packed-column air-stripping is performed employing a cylindrical reactor filled with a packing media. Water entering at the top of the tower flows downward by the force of gravity. A blower at the bottom of the tower blows air countercurrently to the flow of water. Greater contact between the air and the water causes higher removal efficiencies for a packed-column than for diffusive aeration (Reference 2).

A greater specific surface area of packing produces greater contact between air and water, thus, increasing the rate of diffusive mass transfer within a smaller volume. The fluid dynamic performance of a packing media is summarized by the Sherwood Flooding Correlation Curve (Figure B-1.) According to the curve, by increasing the g force applied to the water, the specific surface area of the packing can be increased without adversely affecting the fluid dynamic performance. The RAS uses a packing material made of a metal foam with a high specific surface area and a corresponding high porosity. A higher g force is imparted on the water by rotating the packing media, thus improving the mass transfer (Reference 3). See Table 1 for rotor dimensions and design specifications.

TABLE 1. DIMENSIONS AND DESIGN SPECIFICATIONS OF THE RAS ROTOR

Rotor Dimensions (ft)

Outside Diameter	2.62 ft
Inside Diameter	0.92 ft
Axial Length	1.18 ft
Voidage of Packing	0.96 cuft/cuft
Specific Surface Area	762 sqft/cuft

Design Criteria

Liquid Flow Rate	100 gpm
Gas Flow Rate	2000 scfm
Rotational Velocity	875 rpm
Percent Toluene Removal	99.5%

B. SYSTEM DESCRIPTION

The RAS and incinerator are housed in Building 403 of the Traverse City Air Station, along with two 20,000-pound carbon adsorption units (See Figure 1.) The effluent air from the incinerator leaves the building through a 50-foot stack in the roof. Bypass valving on the influent line allows the water to be divided between the RAS and the carbon tanks, or diverted entirely through the carbon.

The air enters the RAS casing at the outer radius of the rotor and is forced through the packing countercurrent to the direction of water flow (See Figure 2.) The pressure in the RAS casing is held by seals at both ends of the rotor. The effluent air exiting the eye of the rotor is piped to the catalytic incinerator. The air stream is heated to 800 F by a natural gas burner and is then passed across a catalyst. The reaction at the catalyst changes the hydrocarbons in the air stream into carbon dioxide and water. The effluent air from the incinerator passes through a heat exchanger using the waste heat to preheat the influent water to the RAS.

The plumbing layout for the RAS is found in Figure 3. Influent water for the RAS may be taken directly from the pumping well fields or from a 5,000-gallon surge tank. The species and concentration of the contaminants entering the RAS are regulated within the surge tank. The influent water can be preheated with the use of a heat exchanger, or run directly from the well

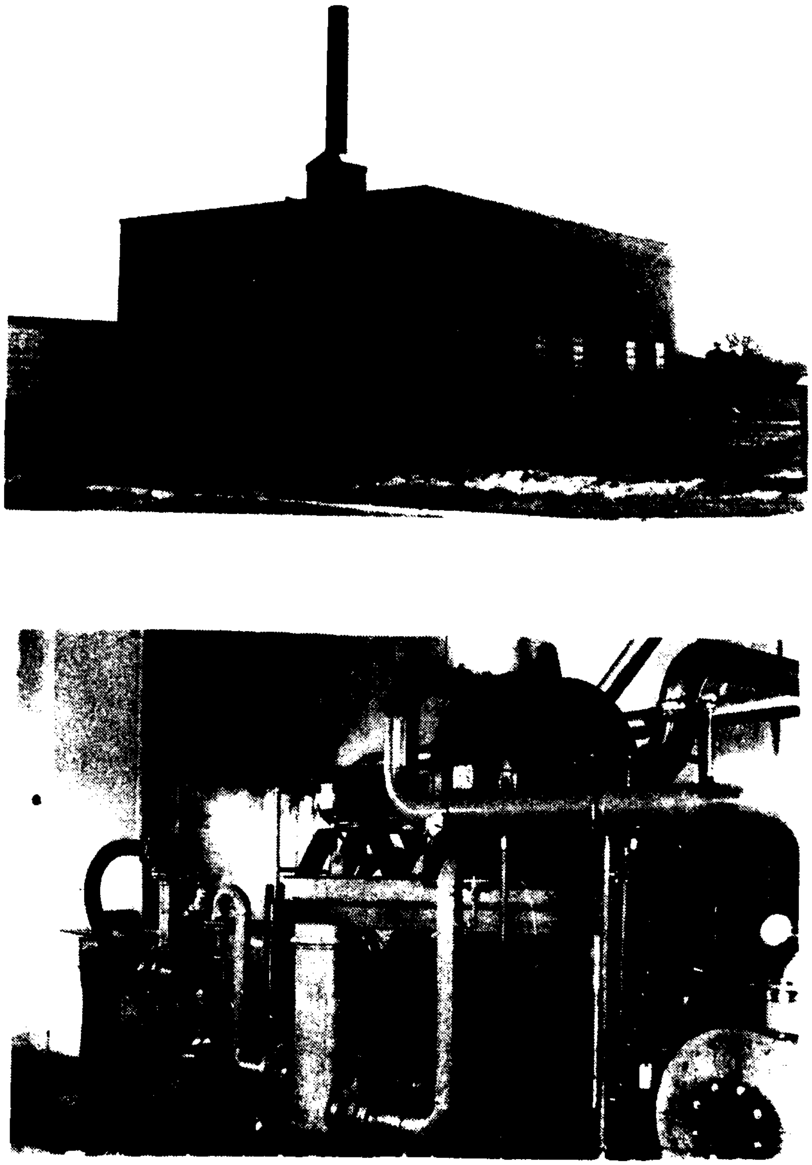

Figure 1. Coast Guard Water Treatment Building and RAS.

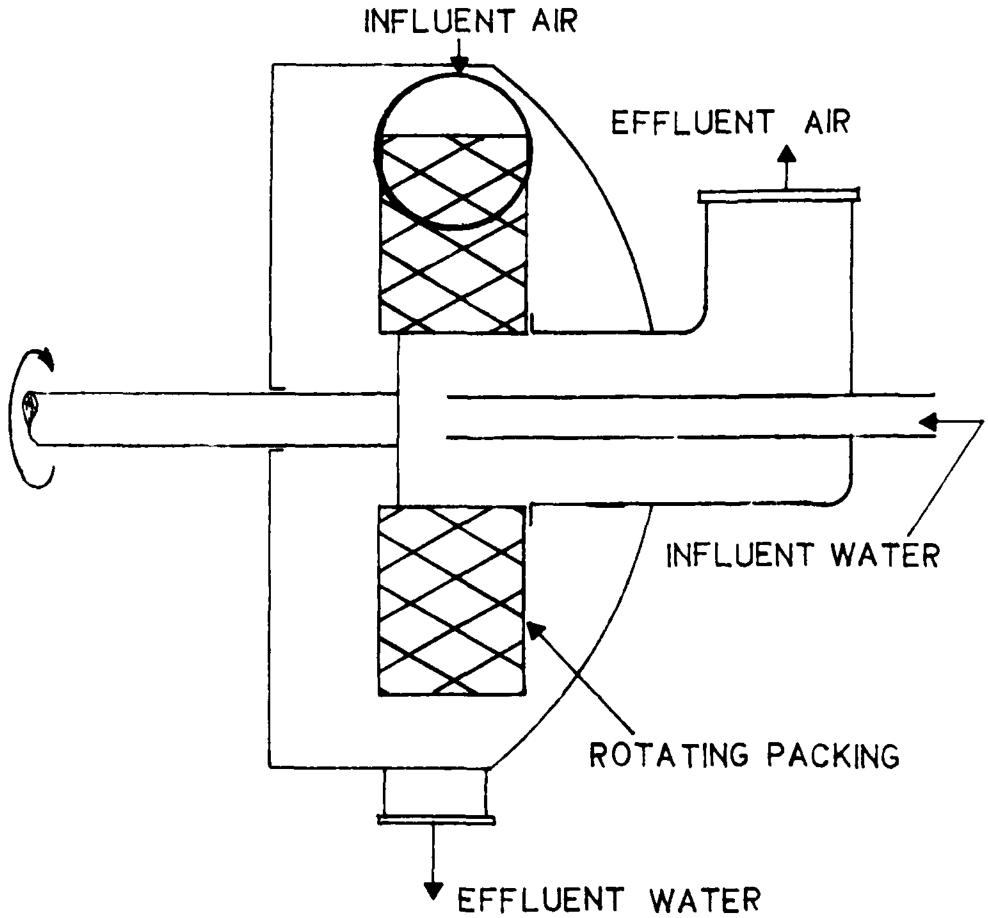

Figure 2. Cross Section of RAS Rotor.

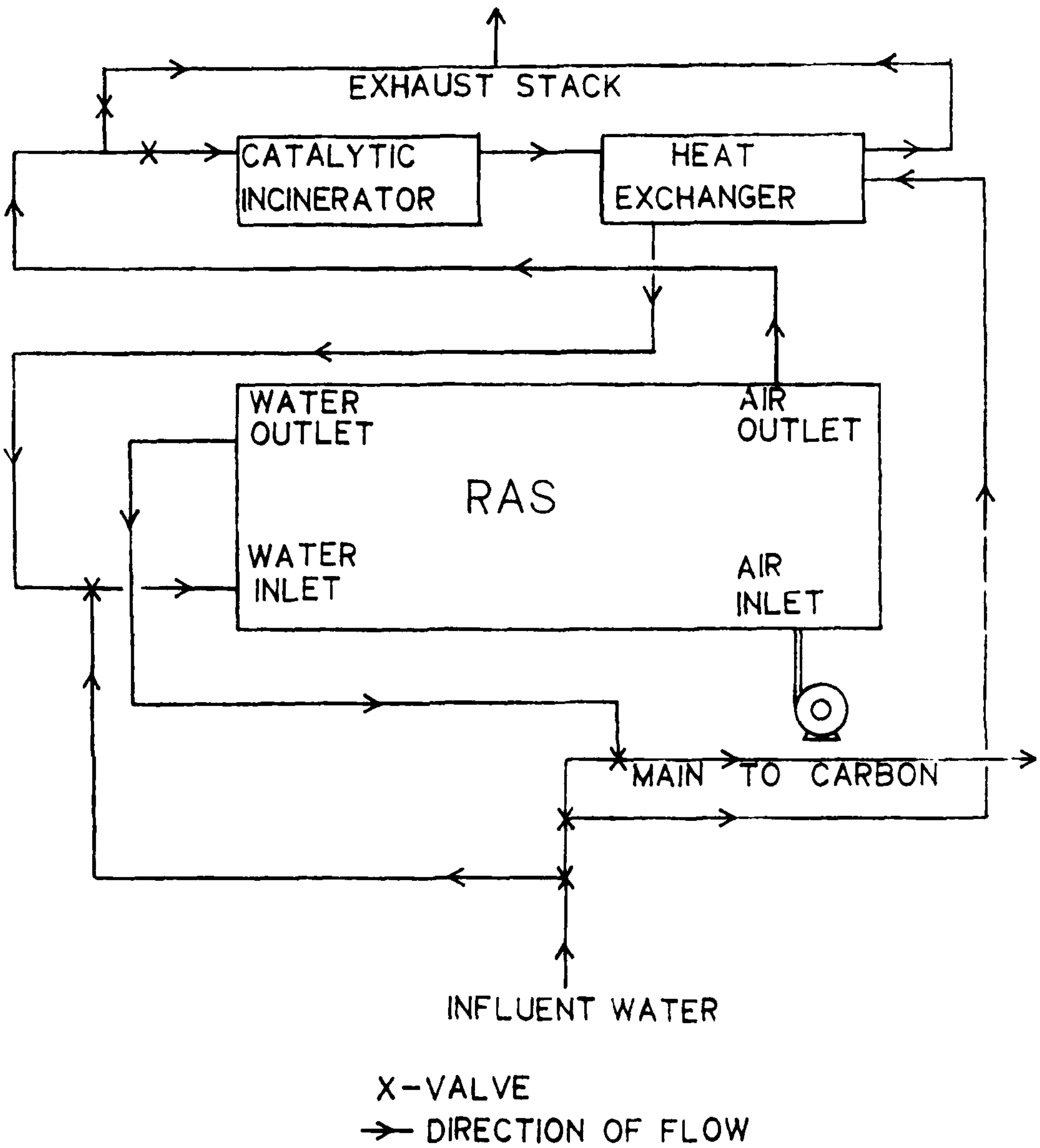

Figure 3. Plumbing Layout of the RAS.

fields. The influent water enters the RAS casing through four distribution rods, evenly spaced within the eye of the rotor. Each distribution rod has a row of drilled holes acting as orifaces for even water distribution. The water exits the distribution rods at a 45-degree angle to the packing, moving in the direction of the packing rotation. This allows the water to enter the rotating packing with little splashback. Water exiting the packing material drains through an 8-inch effluent pipe into a holding basin. The effluent water is pumped from the basin through the carbon polishing units. The influent water sampling port is located approximately 6 feet from the entrance to the rotor. The effluent water sample port is located in a closed line approximately 5 feet from the exit point of the rotor.

C. INSTRUMENTATION

The RAS is equipped with a 20 hp rotor motor, a 20 hp blower motor and a 15 hp discharge pump. The water flow rate entering the RAS is measured with a K72-5-0 King Instrument Rotometer. Liquid and air pressures are measured using dial-type pressure gauges. To prevent the rotor from clogging, an AMF Cuno model 12DC cartridge filter is located on the influent water line. The air flow is measured by a Kurtz Hot Wire Anomometer which has an accuracy of $\pm$ 2 percent. The air flow is displayed on an LCD readout in standard cubic feet per minute (scfm). A Meriam "U" type manometer is used to determine the pressure drop across the rotor packing. The rotational velocity of the rotor is controlled by a Lancer JR Type L1 general purpose inverter. The inverter displays the frequency of electrical current feeding the rotor motor. The rotational velocity of the rotor is calculated from Equation (1):

$$RPM = 14.583(F) \tag{1}$$

where F = Electrical frequency in cycles per second

The acceleration or g force imparted on the liquid is calculated from Equation (2).

$$g = 0.00154\ (RPM)^2 \tag{2}$$

The incinerator is equipped with dial pressure gauges reading differential pressures across the burner and the catalyst. The startup safety sequence and the running burner temperature are controlled by a Honeywell Model R4140L Flame Safeguard Controller. The controller displays the temperature at the burner and the exit side of the catalyst.

SECTION III

EVALUATION

A. DETERMINATION OF OPERATING CONDITIONS

During the first phase of evaluation of the RAS, the air flow rates and the rotor rotational velocity were varied. The liquid temperature was held constant at 54 °F. The liquid flow rate was held constant at flow rates between 80 and 92 gpm. The procedure was as follows: the air flow rate was set and the rotational velocity of the rotor was changed incrementally. Liquid influent and effluent samples were taken for each combination of operating conditions. After the range of rotor velocities had been covered, the air flow rate was changed. The same range of rotor velocities was covered at the new air flow rate. This procedure was followed for air flow rates ranging from 140 to 605 scfm.

The criteria for acceptance of a run are: (1) Liquid flow rate change less than 1 gpm; (2) Liquid temperture change less than 1 °F; (3) Air flow rate change less than 10 scfm; and,(4) Rotor velocity change of less than 0.14 rpm. If the above conditions were not met, then the run was rejected. These experiments were performed in the first 40 runs using influent water containing benzene and toluene concentrations of approximately 100 ppb and 90 ppb, respectively. The data pertaining to these runs are found in Appendix D.

The removal efficiency of the contaminants increased with increasing air-to-water ratios. Increasing the air-to-water ratio above 40:1 (cfm/cfm) produced less than 1 percent increase in the removal efficiencies. This is shown in Figures 4 and 5. Increasing the rotational velocity of the rotor increased the removal efficiencies of the contaminants at constant air-to-water ratios. Increasing the rotational velocity above 700 rpm produced less than 1 percent change on the removal efficiency. These results are shown in Figures 4 and 5.

The results of the first phase of experimentation showed optimum operating conditions for influent waters in the range of concentrations found at the US Coast Guard, Traverse City, MI to consist of a rotor rotational speed of 450 to 700 RPM and a gas-to-liquid ratio of 30 to 40 (cfm/cfm).

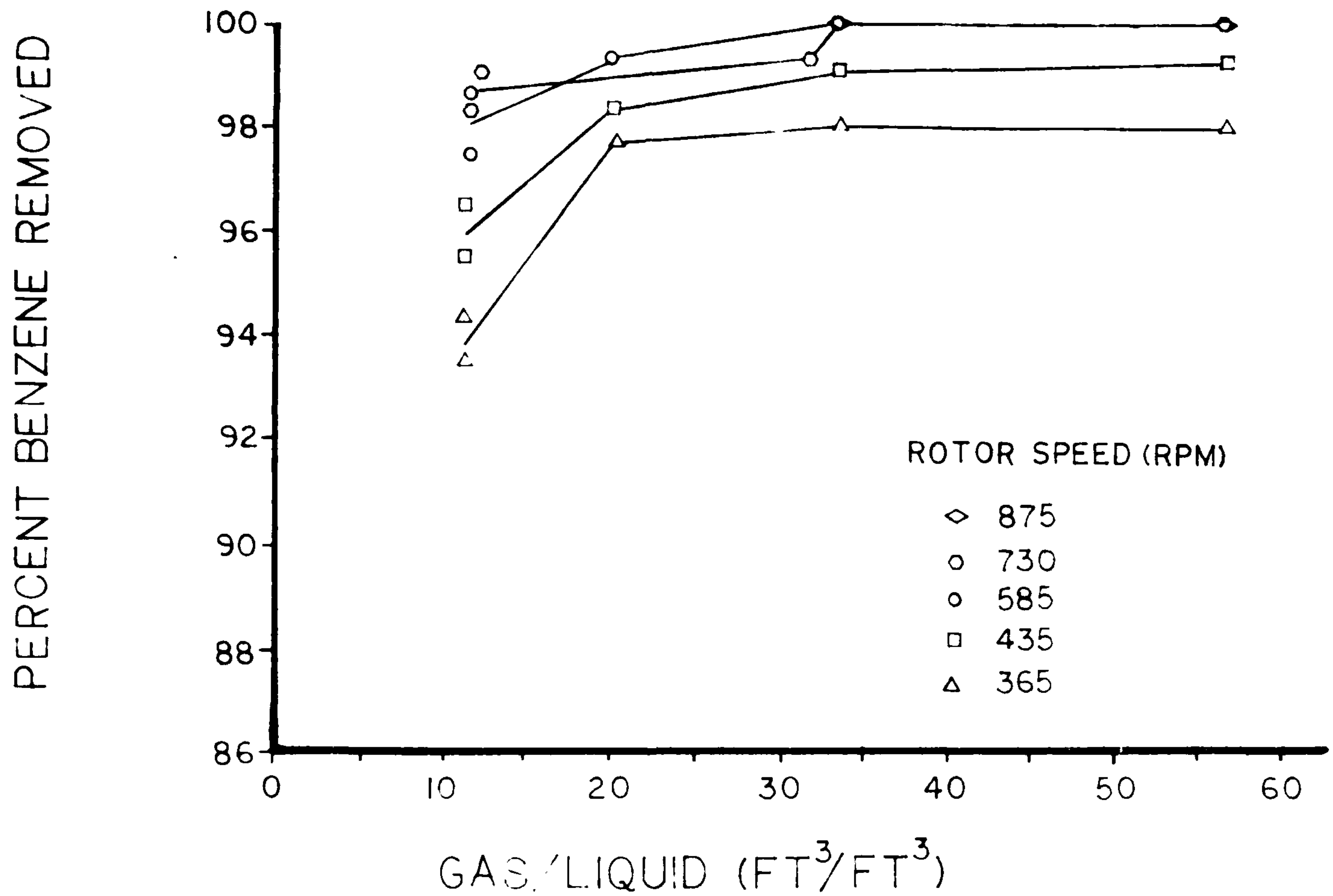

Figure 4. Benzene Removal Efficiency vs. Gas-to-Liquid Ratios (Water Flow, Q, Range = 80-92 gpm; T = 54°F).

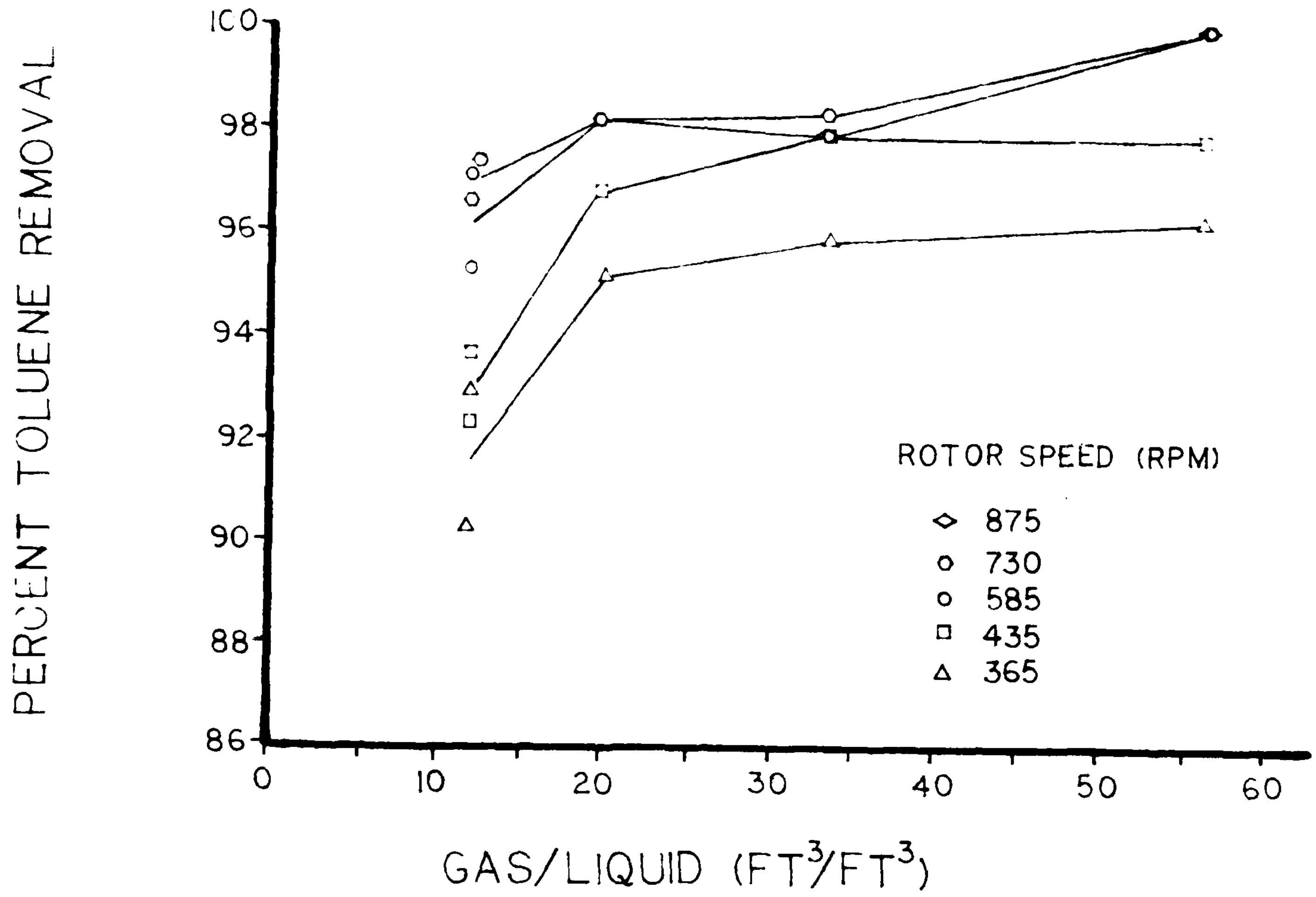

Figure 5. Toluene Removal Efficiency vs. Gas-to-Liquid Ratios (Water Flow, Q, Range = 80-92 gpm; T = 54°F).

Higher air-to-water ratios were used in the second phase of experimentation to ensure high removal efficiencies at higher influent contaminant concentrations. The second phase of experimentation was conducted on benzene, toluene, trichloroethylene (TCE), tetrachloroethylene a.k.a. perchloroethylene (PCE), and 1,2-dichloroethane (1,2-DCE), varying the concentration of each contaminant.

B. REMOVAL EFFICIENCIES OF BENZENE AND TOLUENE

The removal efficiencies of benzene and toluene were evaluated during the first phase of experimentation. The quantitative limits of the analytical equipment for benzene and toluene are 1.0 and 2.0 ug/L, respectively. To facilitate calculations, any trace value found was given the value of the quantitative limit. The "less than" symbol (<) was placed in front of the effluent concentration in the data to indicate that the actual concentration was less than this value. "Greater than" symbols (>) were used to flag the corresponding removal efficiencies.

The RAS proved to be very effective in air-stripping benzene and toluene from contaminated water. The removal efficiencies were in excess of 98 percent under most combinations of operating conditions. Removal efficiencies of 99.9 percent were found to be obtainable for influent concentrations representative of the groundwaters treated at the Coast Guard Base.

A "breakpoint" in the removal efficiency with increasing gas-to-liquid ratios holding liquid flow rate constant between 80 and 92 gpm is seen on the graphs showing benzene and toluene removal efficiencies vs. gas/liquid ratios (Figures 4 and 5.) A breakpoint occurs in the graph near gas-to-liquid ratios of 20:1 (cfm/cfm). Before the breakpoint, small increases in the gas-to-liquid ratio produce large increases in the removal efficiency. After the breakpoint, increases in gas/liquid ratios cause very little increase in the removal efficiency. The break point is about the same for benzene and toluene. Overall, the removal efficiency of toluene is slightly better than benzene. This seems resonable as toluene has a higher Henry's Constant in atm-cubic meters/mole. (See Table 2)

TABLE 2. ESTIMATED HENRY'S CONSTANTS FOR VARIOUS ORGANICS AT 20°C (REFERENCE 2)

Compound	Hc (atm*m^3/mole)
Vinyl chloride	6.4
Dichlorofluormethane	2.1
1,1-dichloroethylene	1.7x10-1
1,2-dichloroethylene	1.7x10-1
Trichlorofluoromethane	1.7x10-1
Methyl bromide	9.3x10-2
Carbon tetrachloride	2.5x10-2
Tetrachloroethylene	2.3x10-2
Chloroethane	1.5x10-2
Trichloroethylene	1.0x10-2
Methyl chloride	8.0x10-3
1,2-trans-dichloroethylene	5.7x10-3
Ethylbenzene	5.7x10-3
Toluene	5.7x10-3
Benzene	4.6x10-3
Chlorobenzene	4.0x10-3
1,1,1-trichloroethane	3.6x10-3
Chloroform	3.4x10-3
1,3-dichlorobenzene	2.7x10-3
Methylene chloride	2.5x10-3
1,4-dichlorobenzene	2.1x10-3
1,2-dichloropropane	2.0x10-3
1,2-dichloropropylene	2.0x10-3
1,2-dichlorobenzene	1.7x10-3
1,2-dichloroethane	1.1x10-3
Hexachloroethane	1.1x10-3
1,1,2-trichloroethane	7.8x10-4
Bromoform	6.3x10-4
1,1,2,2-tetrachloroethane	4.2x10-4
Naphthalene	3.6x10-4
Phenol	2.7x10-7

C. REMOVAL EFFICIENCIES OF CHLORINATED COMPOUNDS

The chlorinated compounds were chosen for evaluation, based on their Henry's Constants. The chlorinated compounds picked for evaluation were TCE, PCE, and 1,2-DCE. These compounds were representative of a wide range of Henry's Constants. (See Table 1) The data from these experiments can be found in Appendix D.

The relationships between removal efficiencies of TCE and PCE and gas-to-liquid ratio at different rotor speeds are shown in Figures 6 and 7. The removal efficiencies of TCE and PCE were in excess of 99 percent for all conditions evaluated. The graphs show no sharp breakpoint for TCE or PCE. Figure 6 does show a slight breakpoint occuring at a gas-to-liquid ratio of approximatly 20:1. Since no breakpoint was seen in the graph for PCE, the breakpoint must occur with gas-to-liquid ratios below 40:1 (vol/vol). These two compounds were stripped at higher efficiencies than benzene and toluene.

Figure 8 shows the effect on removal efficiency of 1,2-DCE from changes in gas-to-liquid ratios at different rotor speeds. The liquid flow rate was held constant between 74 and 77 gpm. The breakpoint for 1,2-DCE occurs between gas to liquid ratios of 60:1 and 80:1 (vol/vol). The greatest romoval efficiency achieved was about 95 percent removal. 1,2-DCE runs with 99 percent removals are seen in the data found in Appendix D. The data points from these runs were not included in the graph as the effluent water samples were taken before the RAS had reached equilibrium. The removal efficiency of 1,2-DCE was significantly lower than TCE and PCE. The relative removal efficiencies of the chlorinated compounds correlate with those that would be anticipated by comparing the Henry's Constants.

D. CONCENTRATION EFFECTS

The effect of increasing influent concentration on removal efficiencies for benzene, toluene, and 1,2-DCE is shown in Figures 9, 10, and 11. No conclusive effects were found on removal efficiency due to changes in the influent concentration, as would be expected since the experiments were conducted inside the Henry's region. These graphs show a slight difference in removal efficiencies for increased concentrations. The differences, however, show no trends and are most likely attributed to errors in experimentation and analysis.

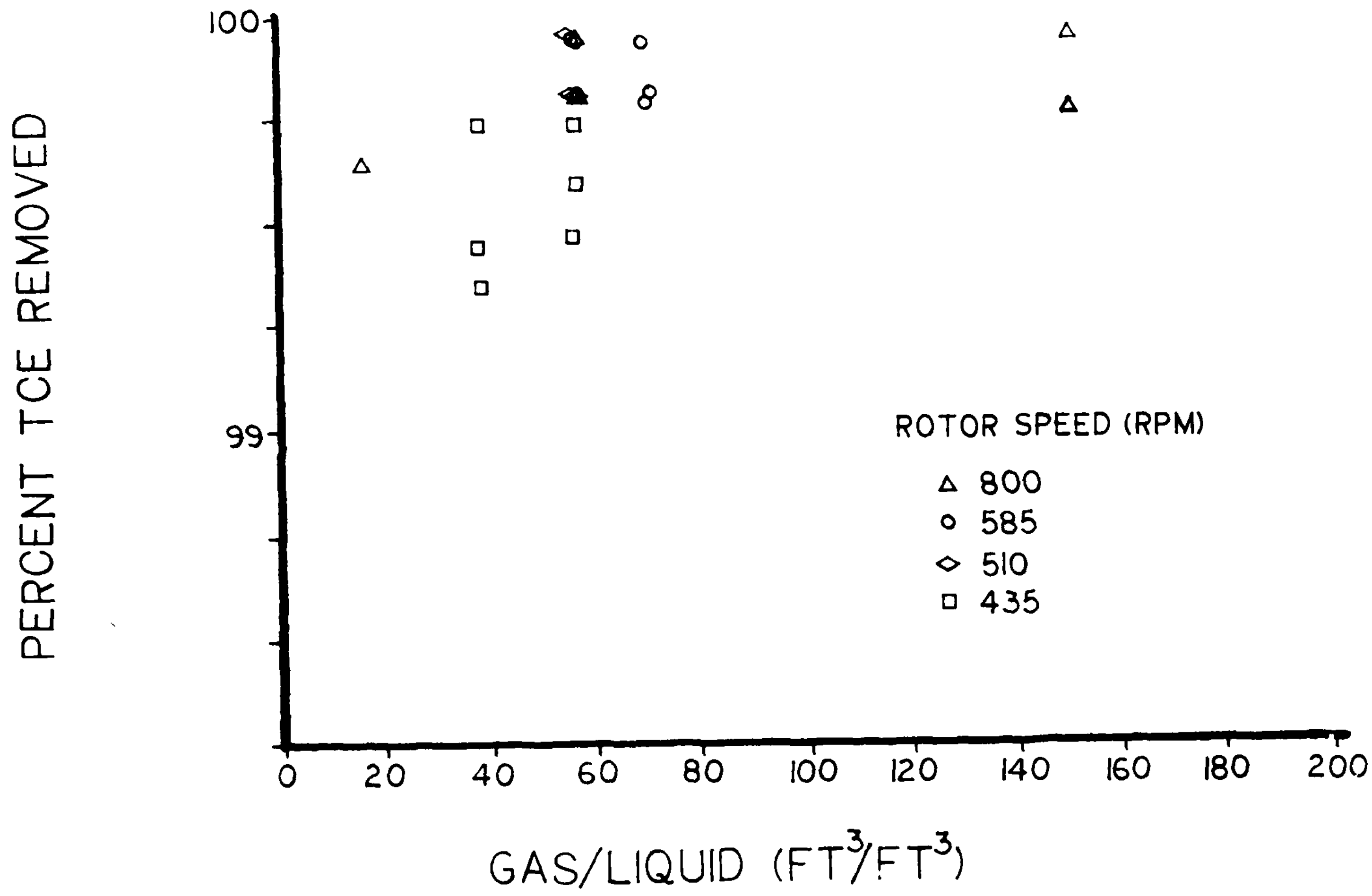

Figure 6. TCE Removal Efficiency vs. Gas-to-Liquid Ratios (Water Flow, Q, Range = 77-80 gpm; T = 54°F).

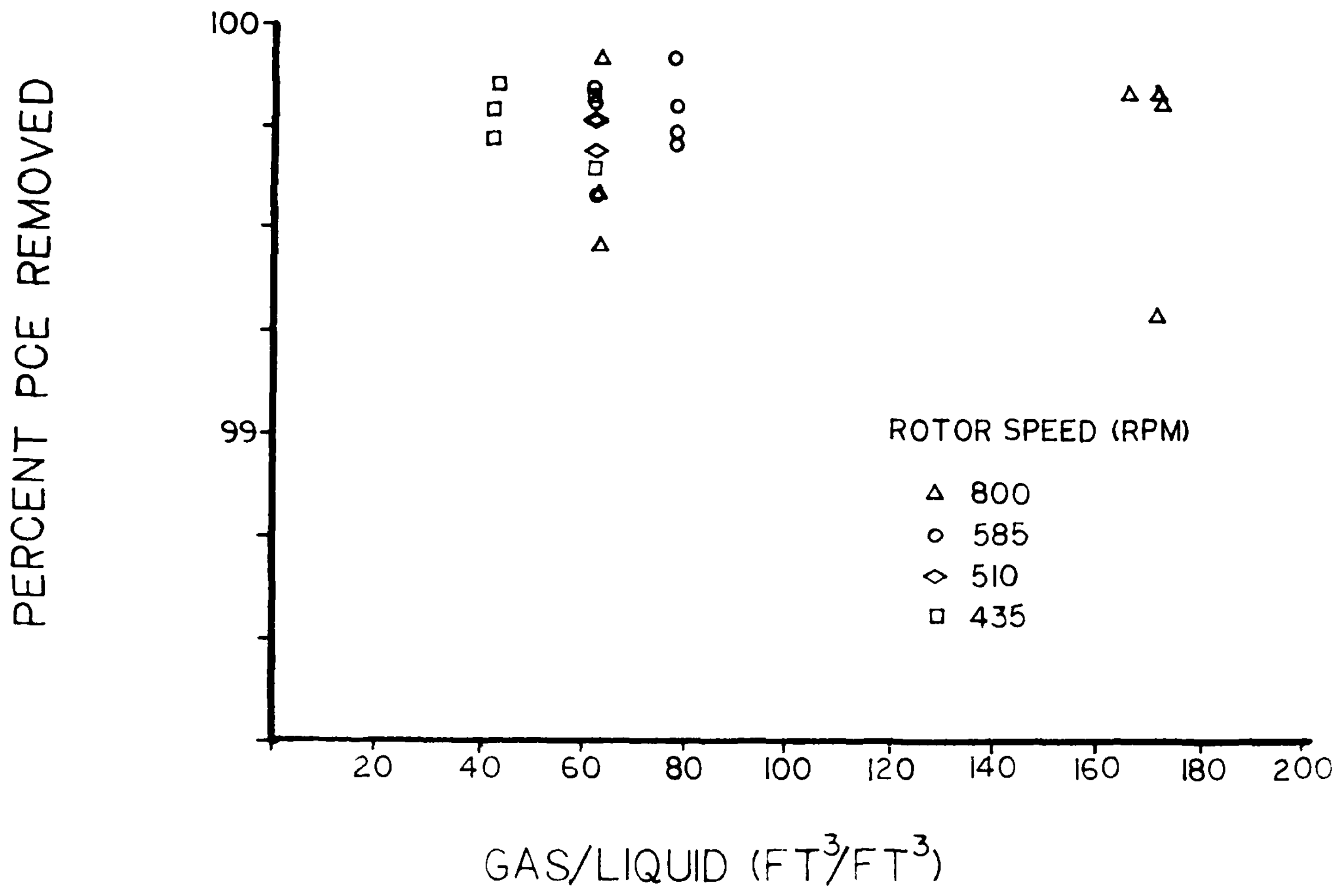

Figure 7. PCE Removal Efficiency vs. Gas-to-Liquid Ratios (Water Flow, [illegible], Range = 68-70 gpm; T = 54°F).

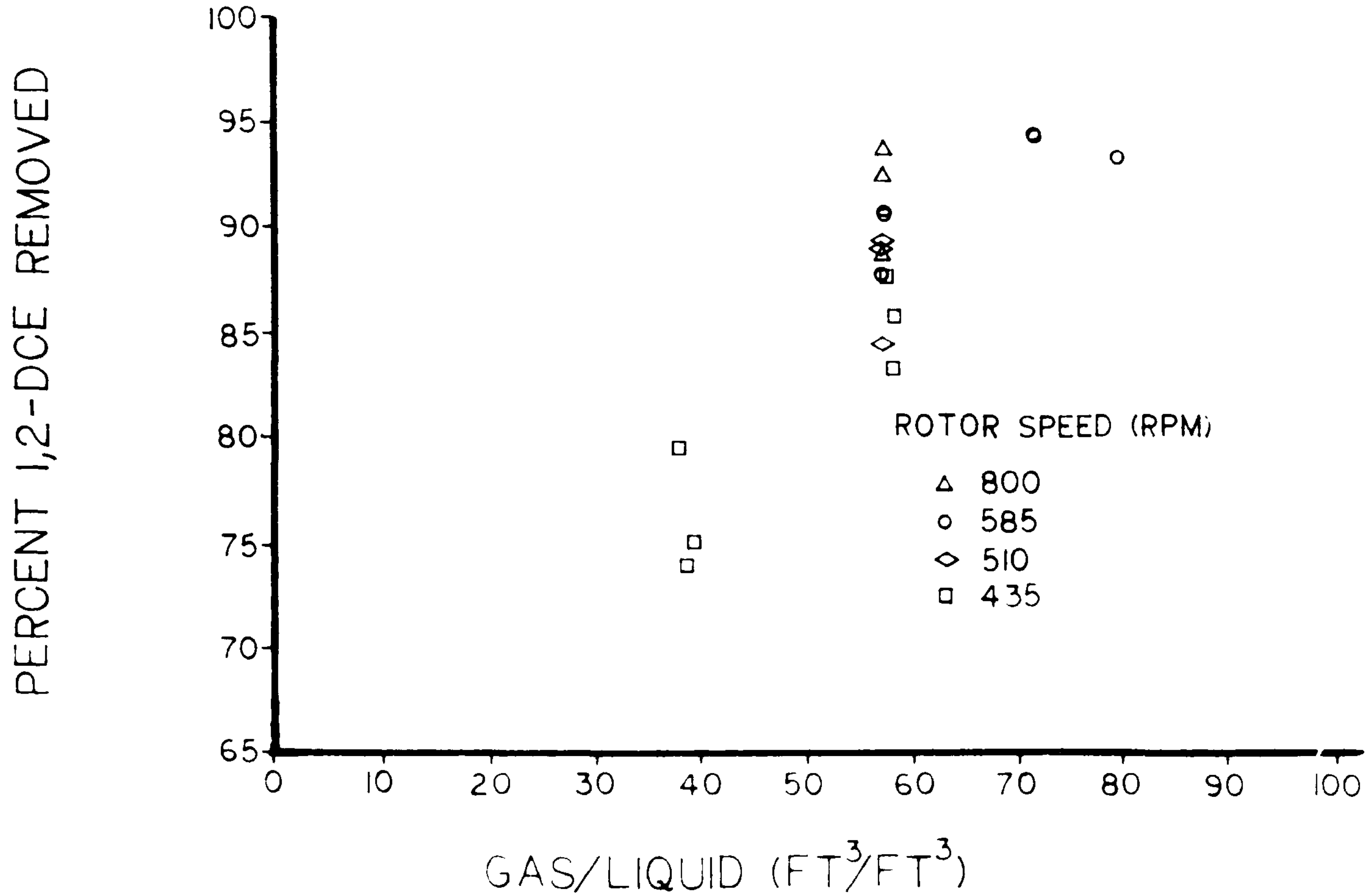

Figure 8. 1,2-DCE Removal [illegible]

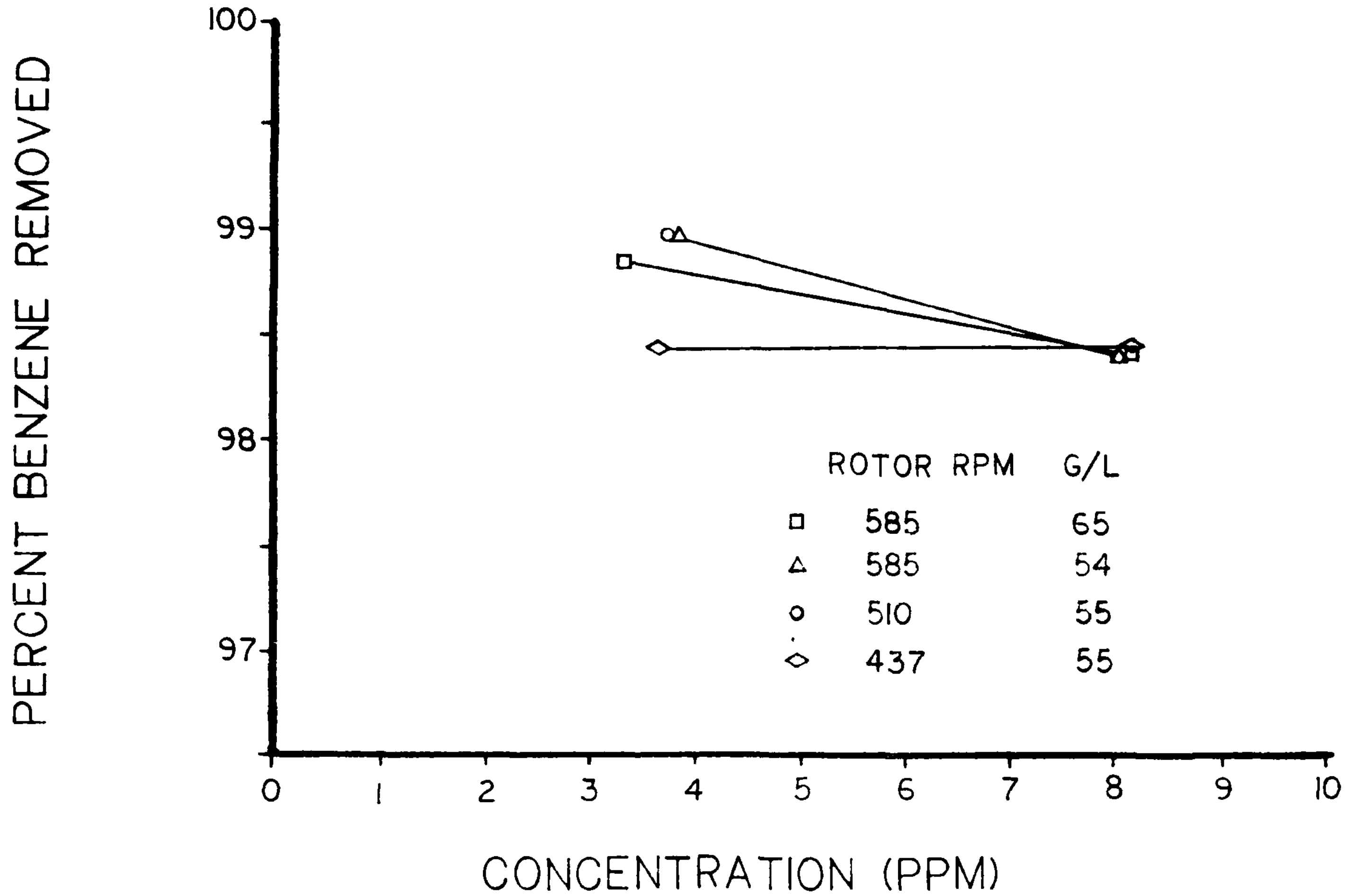

Figure 9. Effect of Concentration on Removal Efficiency for Benzene (Water Flow, Q, Range = 80-86 gpm; T = 54°F).

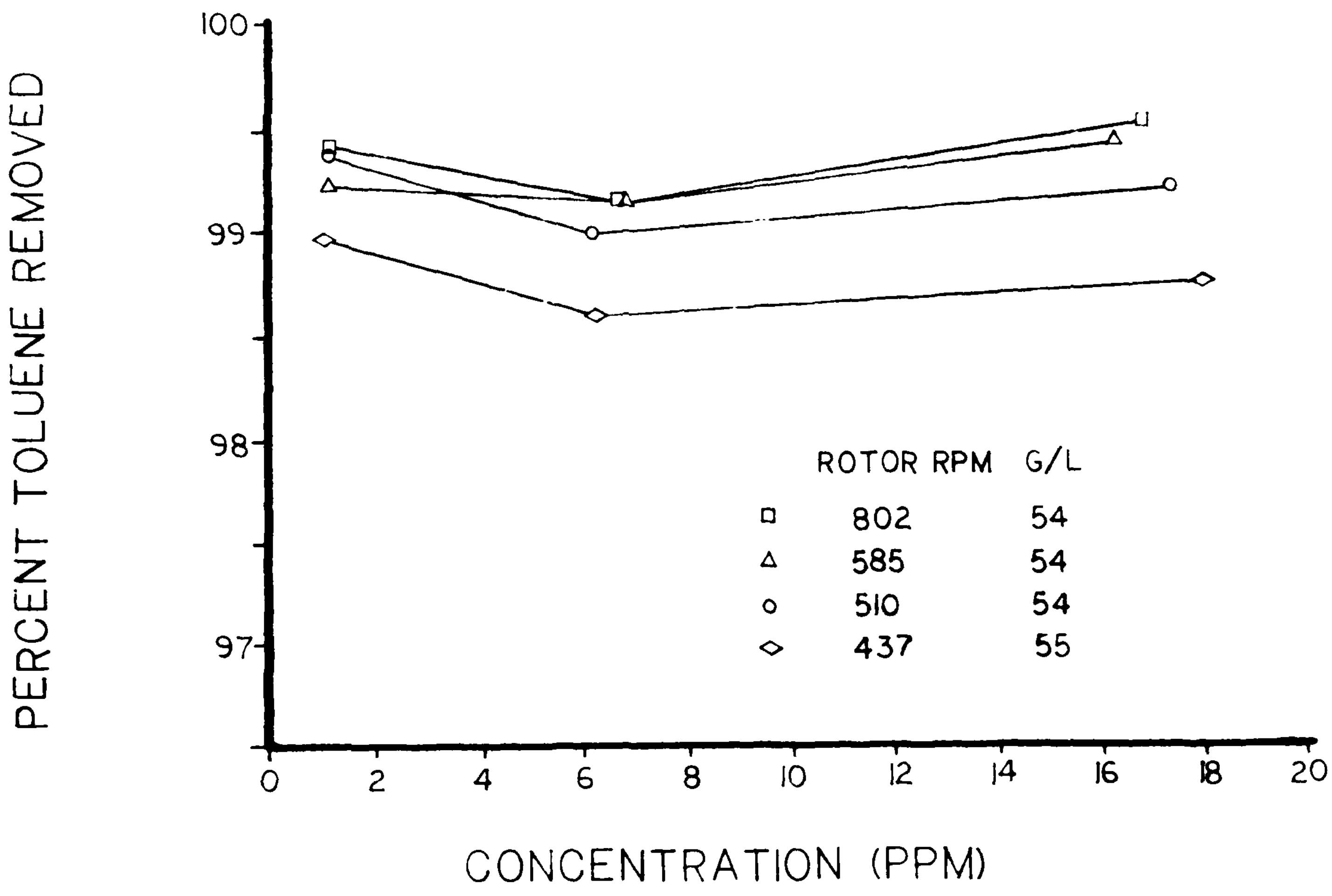

Figure 10. Effect of Concentration on Removal Efficiency for Toluene (Water Flow, Q, Range = 79-84 gpm; T = 54°F).

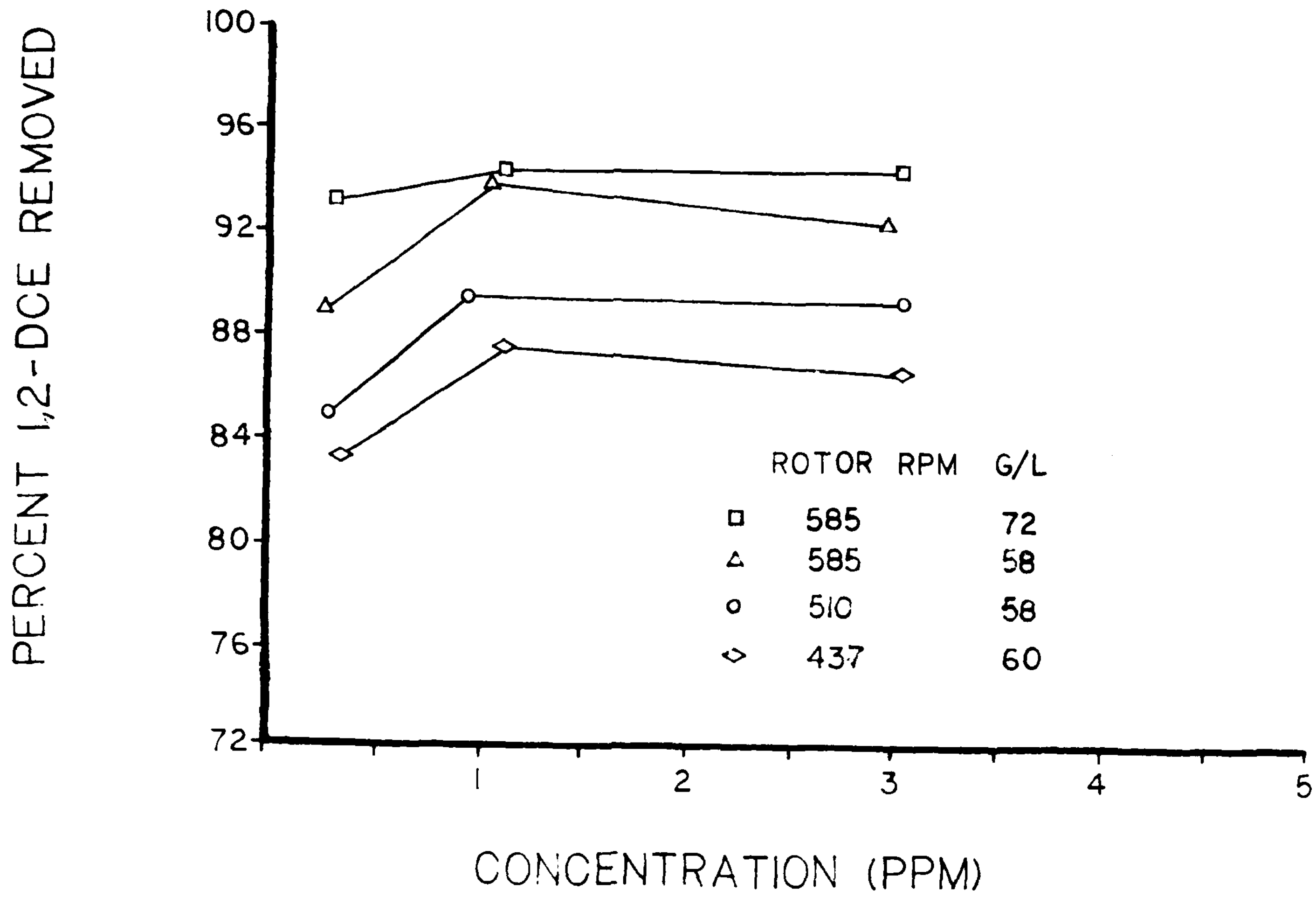

Figure 11. Effect of Concentration on Removal Efficiency for 1,2-DCE (Water Flow, Q, Range = 74-77 gpm; T = 54°F).

E. TEMPERATURE EFFECTS

A very noticable difference in removal efficiency is present due to fluctuations in the liquid temperature. Colder water is stripped less effectively than warmer water. Clean tap water, at 40 °F, was used to mix batches of contaminated water in a surge tank in Runs 40 through 54. The average groundwater temperature in Traverse City is 54°F. Figure 12, comparing removal efficiency of benzene using tap water and groundwater, shows a significant reduction in removal efficiency at the lower temperature.

More studies on temperature effect were conducted by preheating the influent water to the RAS. The influent water from the pumping wells was preheated using the heat exchanger on the incinerator. Only a 6°F to 8°F temperature increase could be acheived at the water flow rates employed. Increasing the liquid temperatures between 54 °F and 62 °F showed no significant effect in removal efficiencies. The remainder of the experiments were conducted using unheated groundwater.

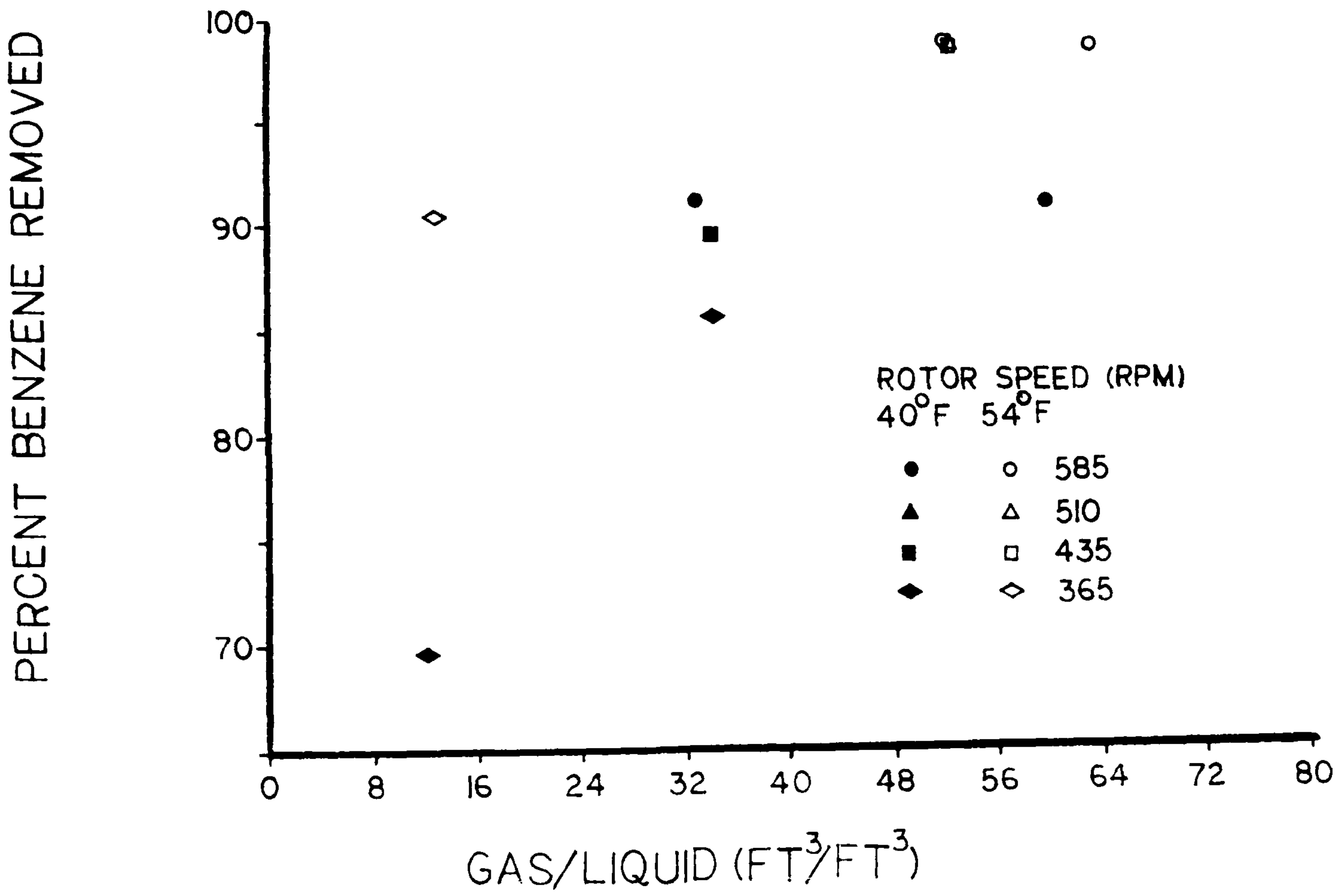

Figure 12. Effect of Temperature on Removal Efficiency for Benzene (Water Flow, Q, Range = 80-92 gpm).

F. FLOODING CORRELATIONS

The use of a rotating packing media for air-stripping is a new technology and relationships describing flooding characteristics have not been developed. Sudden, sharp increases in the differential air pressure across the packing media is the first indication of an approaching flood condition. Figure 13 shows the pressure differential across the rotor at varying rotor velocities for several different gas-to-liquid ratios at a liquid flow rate of 86 $\pm$ 6 gpm. There is a minimum pressure differential for each gas-to-liquid ratio. In an effort to provide some information concerning conditions during operation, the Sherwood Flooding Correlation (SFC) for dumped rings (Figure B-1) is used to determine percent flood at the minumum pressure differential across the rotor. These values are found in Table 3.

TABLE 3. CALCULATED PERCENT FLOOD FOR GIVEN GAS-TO-LIQUID RATIOS AT MINIMUN PRESSURE DIFFERENTIAL CONDITIONS

AIR/WATER (cfm/cfm)	CALCULATED PERCENT FLOOD
G/L = 57	41%
G/L = 34	35%
G/L = 20	34%

Using a relationship developed for packed columns, to describe the flooding characteristics of a rotating media, may not be totally accurate, but it does allow relative comparisons of flooding conditions between different experimental runs. Sample calculations for percent flood can be found in Appendix B.

G. MASS TRANSFER COEFFICIENTS

To determine the mass transfer coeficient (KLa) for the RAS, a formula was used which determines the slope of a line intersecting the origin and a single point of evaluation. According to Gossett (Reference 4) determining KLa in this manner can produce minor errors. Since the RAS uses a rotating packing, sampling along the length of the packing is not possible. Gossett (Reference 4) also states that using the influent and effluent samples for determining KLa can lead to errors. The influent and effluent samples were used for determing KLa's since they are the only samples which can be taken with the RAS.

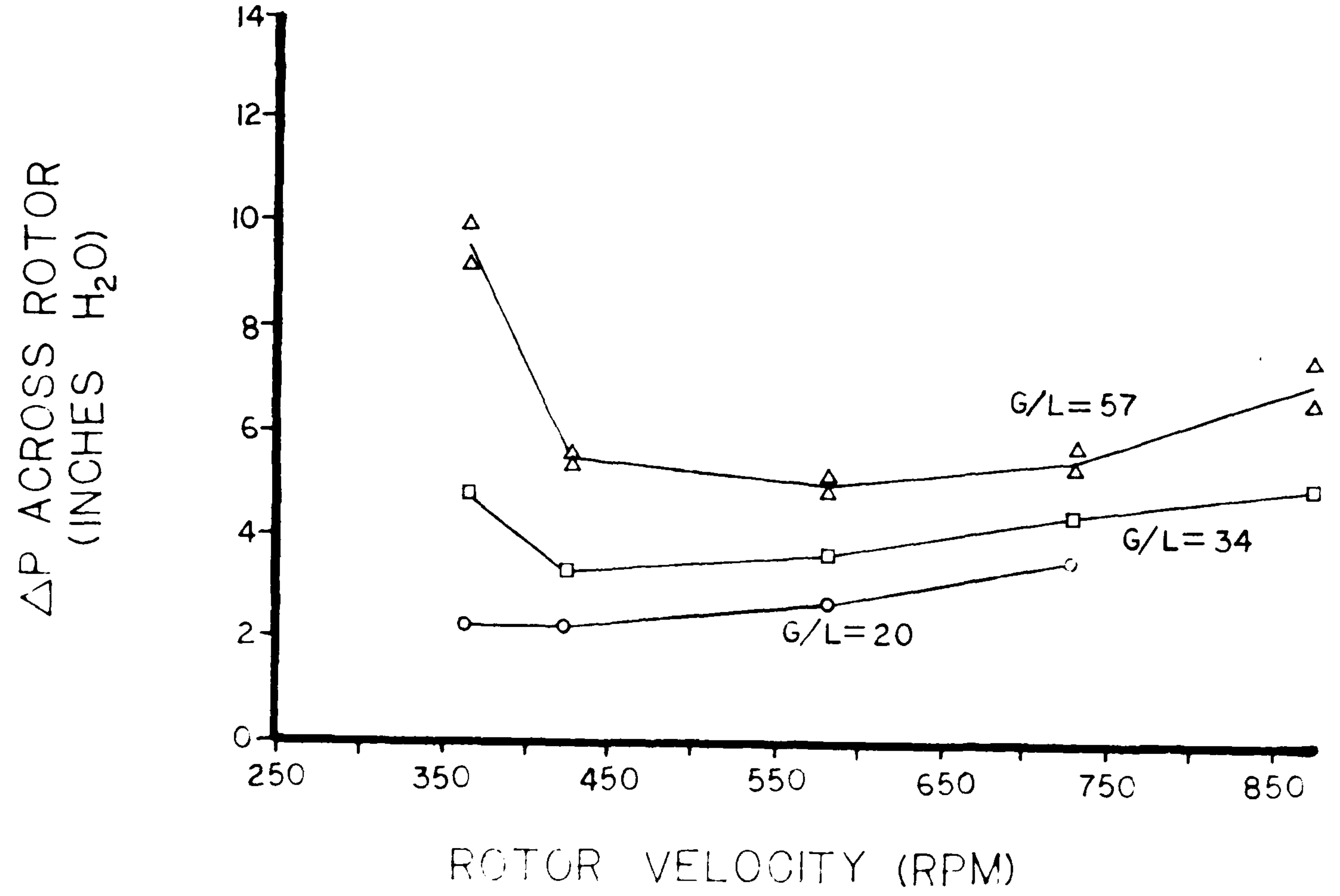

Figure 13. Pressure Drop Across the Rotor for Varying Rotor rpm (Water Flow, Q, Range = 80-92 gpm; T = 54°F).

Sample calculations for KLa determination are found in Appendix B.

Figure 14 shows benzene KLa's vs. rotor speed at different gas-to-liquid ratios while the liquid temperature was held constant at 54 °F. Increasing the rotor speed increases the KLa until 730 rpm then the KLa decreases slightly at 875 rpm. Figure 15 is a graph comparing benzene Kla's vs. gas-to-liquid ratio over the range of water and air flow rates studied, holding the rotor speed, and the temperature constant. KLa appears to vary only slightly with air flow rate, as might be expected from previous work on CCPC.

The mass transfer characteristics of the RAS are improved ten to fifteenfold compared with mass transfer characteristics of a CCPC. The reasons for the improved mass transfer are as follows:

1. There is a greater area of contact between the air and the water for a given volume of packing in a RAS. The greater area of contact allows for a greater amount of diffusion from the liquid to the gas.

2. The increased g force imparted on the liquid creates thinner liquid films coating the packing media. This increases the area of contact between the air and water "a" which in turn enhances the overall mass transfer KLa (Reference 5).

Kla's for benzene experiments can be found in Appendix D.

H. COMPARISON OF ROTARY AND PACKED COLUMN AIR-STRIPPING

The RAS is a prototype air-stripper and any direct comparison with an "optimum" CCPC would be biased. The best way to relate a CCPC with the RAS is to use the most efficient operating conditions for the RAS in a design equation for the CCPC. The conditions picked for the RAS are 100 gpm, 600 scfm,

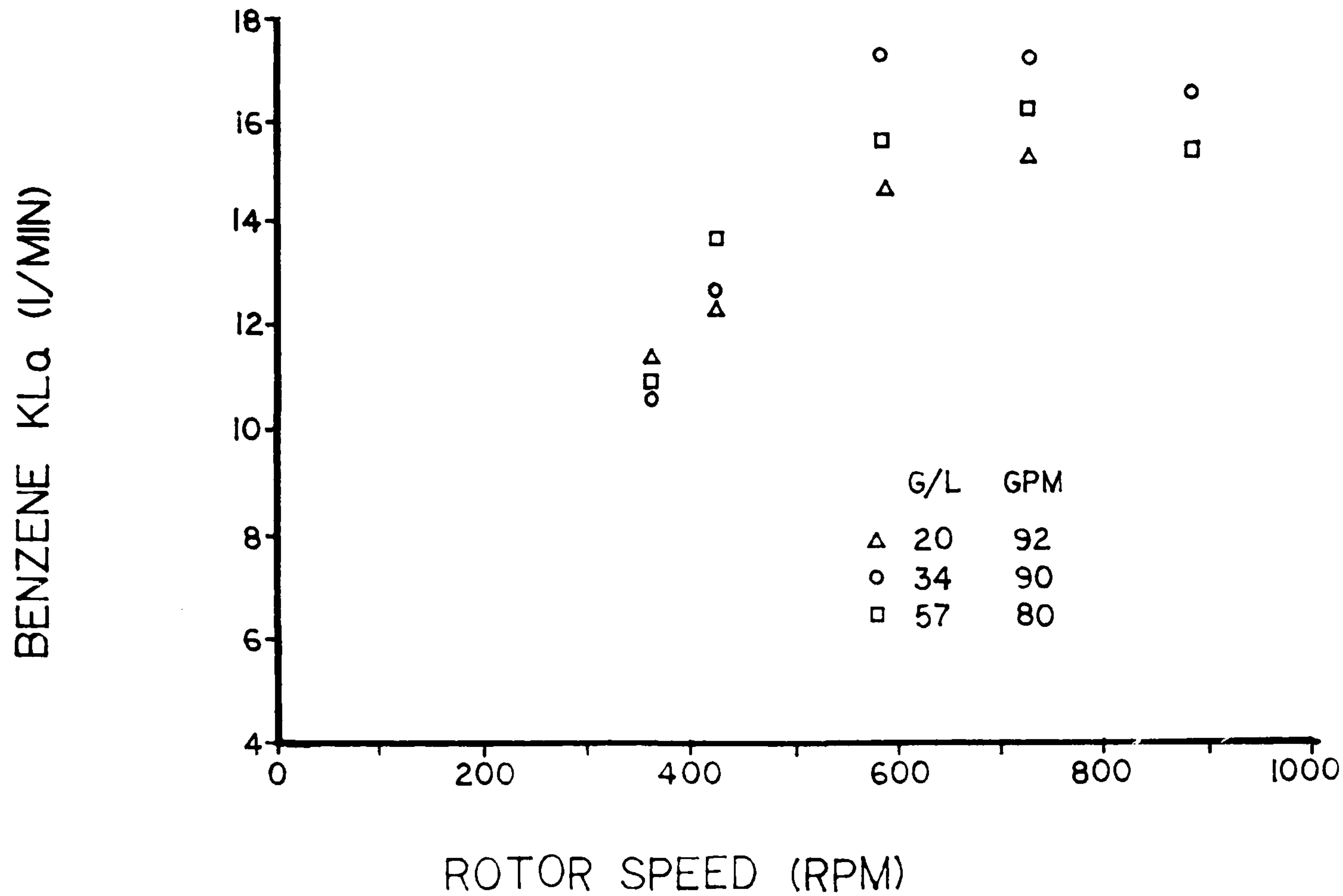

Figure 14. Benzene KLa's vs. Rotor Speed for Different Gas-to-Liquid Ratios (T = 54°F).

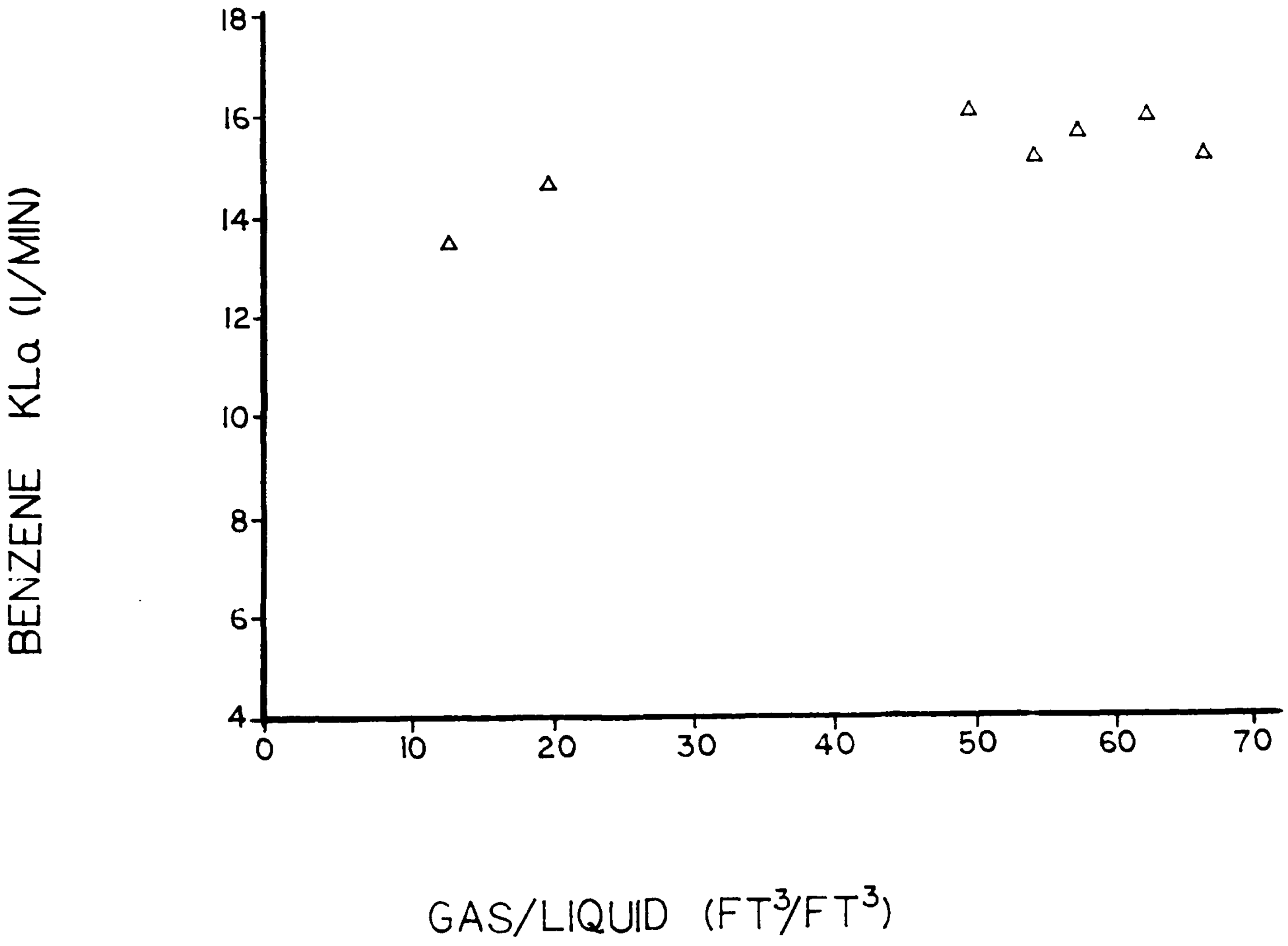

Figure 15. Benzene KLa's vs. Gas-to-Liquid Ratios (Water Flow, Q, Range = 72-92 gpm; Rotor Speed = 585 rpm; T = 54°F).

585 rpm, and 99 percent removal. An "optimum" liquid loading rate for the CCPC is 30 gpm/sqft. The design equation from Gossett (Reference 4) is:

$$(Z)(A) = \frac{L}{KLa}\left[\frac{\ln\left(\frac{Ci}{Ce} - \frac{(R)(T)}{(Aw)(Hc)}\left(\frac{Ci}{Ce} - 1\right)\right)}{1 - \frac{(R)(T)}{(Aw)(Hc)}}\right]$$

Where: Z = Packing height
A = Cross sectional area = 0.307 sqM
(using 100 gpm and loading of 30 gpm/sqft)
Ci = Influent concentration = 3696.70 ug/L
Ce = Effluent concentration = 38.42 ug/L
R = Gas constant = 8.206×10^{-5} atm-cuM/mole- K
T = Temperature in K = 295 K
Aw = Gas/liquid (vol/vol) = 44.8
Hc = Henry's Constant = 0.0046 atm-cuM/mole
L = Liquid flow rate = 0.379 cuM/min

Evaluating the CCPC design equation with the conditions from the RAS gives a CCPC with a diameter of 2.1 feet and a height of 17.5 feet. This shows that for the same performance the CCPC packing bed depth needs to be 20 times greater, but the cross-sectional area of the packing is half as great as for the RAS.

For a CCPC air-stripper to get the same removal efficiency as the RAS a much larger volume of packing is needed.

I. OPERATION AND MAINTENANCE

Between December 1985 and January 1986 the RAS was operated for 12 days, for at least 5 hours each day. A problem was encountered maintaining the liquid flow rates. This problem also affected the experiments. Clogging of the in-line solids filter was the reason for the loss in liquid flow rate. The clogging is due to a biological iron precipitate present in the influent water from the pumping wells. The precipitate clogs the filters, increasing the influent pressure and decreasing the liquid flow rate. The filter cartridges are theoretically disposable, but clogging occurred too frequently to economiclly warrant disposing of the filters every time they clogged. The filters were scrubbed with water whenever they clogged up significantly. The filters had to be immersed in muriatic acid to dissolve the iron in the

inner parts of the filter after only a few cleanings by scrubbing. There was no clogging of the rotor at any time during the experimentation.

Oil levels for the motor shafts were checked on a monthly basis. There was no need to add any oil at any time during the experimentation. Ten minutes per month were required to grease the mechanical coupler between the rotor and the rotor motor.

Water carryover into the effluent airstream was a significant problem encountered in operation of the RAS. This problem was worsened by increased air flow rates. The water blown by would flow into the catalytic incinerator through the exhaust air ducting. The manufacturers of the incinerator (Torvex) said water blowing into the incinerator would cause the catalyst to spall, effectivly decreasing its ability to catalyze the incineration reaction. The problem was due to two reasons. Water exiting the liquid distribution rods would hit the packing and splash back into the effluent air stream. Also, water exiting the drilled orifices in the distribution rods would drip into the effluent air stream to be carried away. In an attempt to remedy both situations, larger holes were drilled in the rods so the velocity of water leaving the orifices was reduced. The larger holes had little or no effect on the carryover.

J. TREATMENT COSTS FOR ROTARY AIR-STRIPPING

The point of maximum removal efficiency at the lowest rate of power consumption was chosen for the electrical consumption cost calculation. The operational conditions of the RAS producing 99.9 percent removal of benzene from a 90 gpm liquid influent from the Coast Guard's pumping wells at the lowest rate of power consumption are: 600 scfm air flow and 437 rpm rotor rotational velocity (See Figure 16.) The electrical consumption for the RAS (rotor motor, discharge pump, and blower motor) operating at these conditions is about 16 Kw. The shape of the curve relating power consumption to variations in gas-to-liquid ratios is attributed to the energy required to run the rotor motor. The rotor rotational velocity must be increased to achieve greater contact between the air and water at lower gas-to-liquid ratios. (Refer to section on Mass Transfer) There is a greater increase in electrical consumption for an increase in the rotor velocity than for an increase in the air flow.

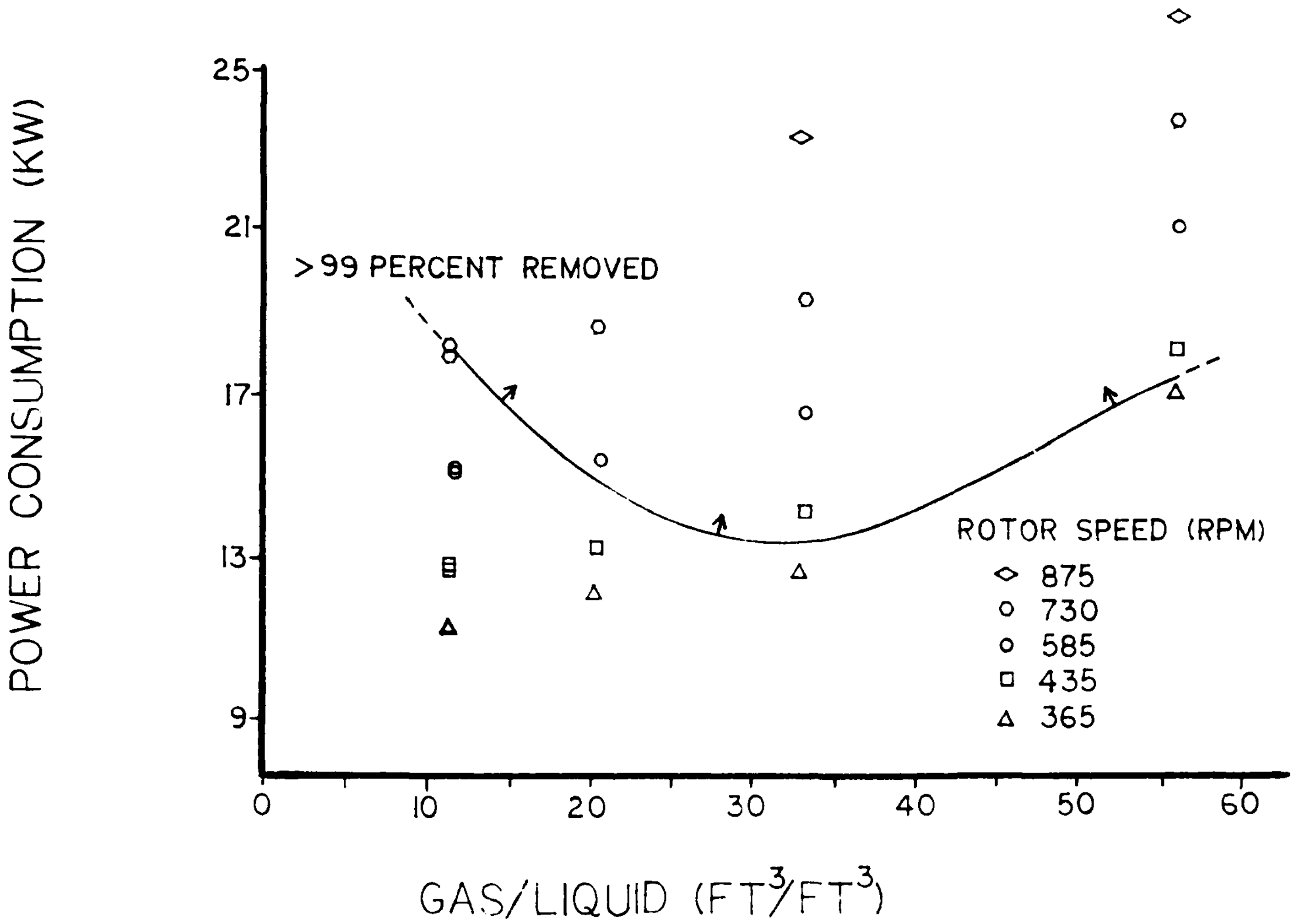

Figure 16. Power Consumption of RAS vs. Gas-to-Liquid Ratios (Water Flow, [illegible], Range = 80-92 gpm; T = 54 F).

Assuming the average cost of electricity in Traverse City, MI. is \$0.07/kw-hour. The cost of running the RAS per 1000 gallons of water treated is:

(16 kw) x (\$0.07/kw-hour) x (hour/60 min) x (min/90 gal) x 1000

= \$0.207 / 1000 gallons water treated

At the same cost for electrical power the packed column at Wurtsmith Air Force Base costs \$0.168 per 1000 gallons of water treated (Reference 2).

SECTION IV

SAMPLING PROCEDURES AND SAMPLE ANALYSIS

A. SAMPLING PROCEDURE

Samples were taken after the RAS reached equilibrium in the experimental operating configuration. The liquid residence time is calculated to be less than 1 minute. Five minutes was assumed to be sufficient time for the system to reach equilibrium. During continous operation samples were collected after an hour of operation. The results did not deviate from the samples collected after 5 minutes. The sampling lines were allowed to purge for at least 30 seconds to assure a representative sample of the water. After purging, the water flow rate was reduced to less than 200 milliliters per minute. Samples were collected in 120-milliliter crimp-top vials and immediately capped with Teflon®/rubber septa. To avoid volatilization of the contaminants, the sample bottles were filled by allowing the water to gently run down the side of the bottle. The bottle was slightly overfilled, leaving a convex meniscus on the top. No air bubbles were left in the bottle. Influent samples were taken first, then the effluent sample. The samples were refrigerated until the time of analysis. The analysis was performed on the same day the samples were taken to avoid volatilization of contaminants through the septa seals.

B. SAMPLE ANALYSIS

Benzene and toluene samples were analyzed using the EPA method 5020, Headspace Analysis for Volatile Organic Hydrocarbons. The samples were analyzed using a Hewlett-Packard model 5710A gas chromatograph, with a flame-ionization detector, and a Hewlett-Packard model 3392A integrator. Twenty milliliters of the water sample were syringed out of the sample bottle, simultaneously being replaced by the same volume of ambient laboratory air. The samples were placed in a water shaker bath which was held at 90°F. At least 15 minutes were allowed for the water sample to reach equilibrium with the air headspace within the sample bottle. Between 1 and one-tenth of a milliliter of the air in the headspace was extracted by syringe and injected into the Gas Chromatograph. The volume of air analyzed depended on the predicted contaminant concentration and corresponding programmed method of analysis. The quantitation limits for benzene and toluene are 1 and 2 μg/L, respectively.

The analysis of the chlorinated hydrocarbons, TCE, PCE, and 1,2-DCE, was performed, using one of two methods, depending on the predicted contaminant concentration. If the concentration was predicted to be greater than 50 µg/L, then the headspace technique was used as described above. If the concentration was assumed to be less than 50 µg/L, then the analysis was performed as follows: Five mLs of sample were pipeted into a sparging vial. The vials were sparged with nitrogen gas for 15 minutes. The effluent gas of the sparging process was collected on sorbent tubes. The contaminants were desorbed from the tubes using a Unacon Envirochem model 810 desorber. The sample was automatically transferred from the desorber to a Tracor model 540 Gas Chromatograph with a Hall Detector. A Hewlett Packard model 3390A integrator, monitoring the output of the Hall detector, calculated the concentration of contaminant in the water sample. The limit of quantitation of the Tracor gas chromatograph for the chlorinated contaminants is 0.1 µg/L. Information regarding standards preparation and systems calibration is found in Appendix A.

SECTION V

CONCLUSIONS

Rotary air-stripping is an effective means of removing volatile organic contaminants from groundwater. With the exception of PCE, the removal efficiencies of the contaminants studied were in agreement with what would be predicted from the Henry's Constants. Contaminants with Henry's Constants above 4.0×10^{3} atm-M^{3}/mole were air-stripped with removal efficiencies greater than 98 percent at air-to-water ratios of 35:1 or more. Temperatures much lower than 54 °F noticably affected the removal efficiency of benzene. By using a RAS, mass transfer coefficients can be greatly increased, hence, a much smaller treatment system can be used than a packed-column.

The cost of operation of the RAS is higher than the cost of operating a CCPC air-stripper. The higher cost can be partially attributed to the fact that the RAS installed in Traverse City is a prototype model. Economic considerations were not the main emphasis of the design.

SECTION VI

RECOMMENDATIONS

Rotary air-stripping achieves high removal efficiency in a small space. Using a rotating packing allows for greater acceleration to be imposed on the water, thus, allowing for greater air-to-water ratios than a CCPC air-stripper, without flooding. Future reasearchers should:

1. Develop improved relationships for mass transfer determinations at various distances from the axial center of the rotor.

2. Conduct laboratory experiments on different types of rotor packing materials to better determine the relationships between cost of operation and removal efficiency.

3. Conduct more experiments on low Henry's Constant contaminants to test the RAS's ability to strip these problem pollutants.

4. Analyze better mechanical designs for the solids filtration system and the orientation of the rotor. The rotor on the RAS evaluated is cantalevered which necessitates a heavy-duty bearing. The heavy-duty bearing increases the cost and weight of the machine.

5. Use the RAS to evaluate different treatment options for contaminated effluent air streams such as carbon adsorption and biodegradation.

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APPENDIX A

LABORATORY STANDARDS PREPARATION

Gravimetric stock standards were prepared by injecting pure contaminants into methanol, and weighing them to the nearest 1/10th of a milligram. The analytical balance utilized produces significant figures to the nearest milligram, so that additions of more than 100 milligrams produced gravimetric standards accurate to three significant figures. Working solutions were prepared by making dilutions of the stock solution in methanol. All working solutions were capped and refrigerated for storage.

Daily standards for headspace were prepared by injecting an appropriate quantity of working solution into a sample vial. Several concentration levels were stored on the Hewlett Packard 3392A integrator using the external standard method of calibration. Daily standards for the purge and trap system were prepared by injecting an appropriate amount of working solution into septum-top 40-mL vials containing a known amount of organic free distilled water (determined by weight to three significant figures). The standards were treated as water samples for preparation of sorbent tubes. The sorbent tubes were run on the Tracor 540 Gas Chromatograph. The results for several concentration levels were stored in calibration tables on the 3390A integrator using the external standard method of calibration.

APPENDIX B

SAMPLE CALCULATIONS

A. PERCENT FLOOD CALCULATIONS

Sample calculations for determining Percent Flood using the Sherwood Flooding Correlation (SFC) are as follows (Reference 6):

1. Determine the value of the abscissa of the SFC from the following equation:

$$\frac{(L)}{(G)} \times (pG/pL)^{0.5}$$

Where:

L = liquid mass flow rate (lb/min)

G = gas mass flow rate (lb/min)

pG = density of gas = 1.2 (mg/cm^3)

pL = density of liquid =1000(mg/cm^3)

Use:

L = 80 gpm x 8.34 lb/gal = 667.7 lb/min

G = 605 cfm x 0.0752 lb/ft^3 = 45.5 lb/min

$$\frac{(667.7)}{(45.5)} \times (1.2/1000)^{0.5} = 0.51$$

Find this value on the abscissa of the SFC and extend up until the curve for dumped rings is intercepted. Extend horizontally until hitting the ordinate. This gives a value of 0.04. Set this value equal to the equation on the ordinate and solve for Ut as follows:

$$\frac{(Ut)^2 (a) (pG) (m)^{0.2}}{(g)(e)^3 (pL)}$$

Where:

Ut = superficial gas velocity (M/sec)

a = specific surface area = 2500 (M^2/M^3)

pG = density of gas = 1.2 (mg/cm^3)

m = liquid viscosity = 1.0 centipoises

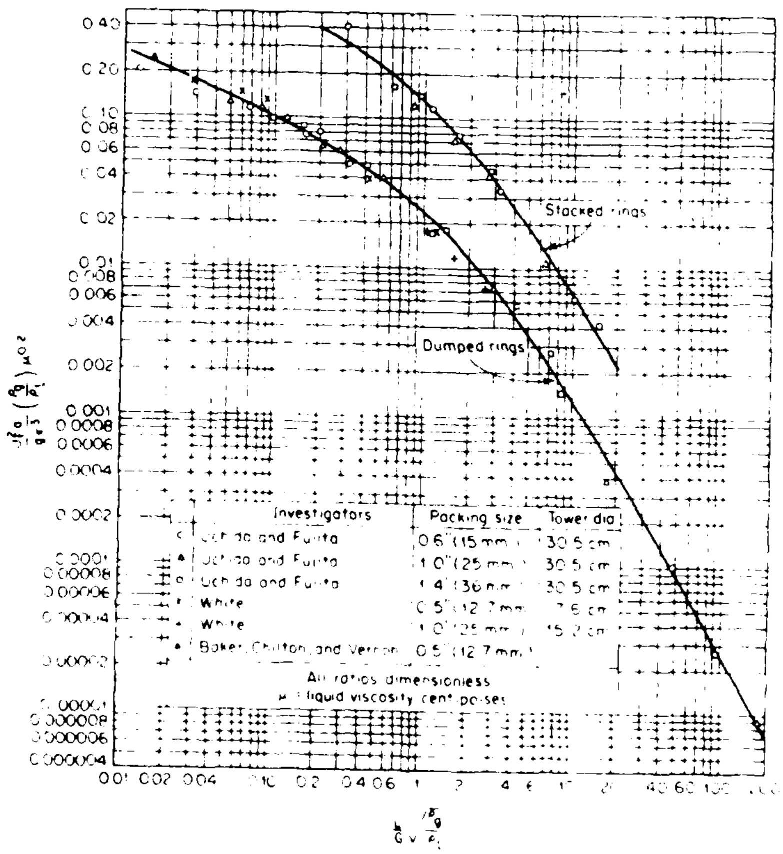

Figure B-1. Sherwood Flooding Correlation Curve. (Reference 6)

g = acceleration in (M/sec^2)

e = percent voidage = 0.96 (unitless)

pL = density of liquid = 1000 (mg/cm^3)

Use: $g = 525\ (M/sec^2)$

$$\frac{(Ut)^2(2500)(1.2)(1)^{0.2}}{(525)(0.96)^3(1000)} = 0.04$$

$Ut = 2.49$ M/sec

Calculated Ut at the conditions in question equals 1.02

Calculated Percent Flood is:

$$\left[1 + \frac{\overline{Ut}\text{ (from graph calculated)} - Ut\text{ (at conditions)}}{(\ -1\ )\ Ut\text{ (calculated from graph)}}\right] X\ 100\%$$

Percent Flood = 41%

B. PERCENT REMOVAL CALCULATIONS

Calculation of percent contaminant removed is as follows:

$$\frac{Ci - Ce}{Ci} \times 100\%$$

Where: Ci = influent concentration

Ce = effluent concentration

Use: Benzene influent = 3301.8 ug/L

Benzene effluent = 38.92 ug/L

$$\text{Percent removal} = \frac{(3301.8) - (38.92)}{(3301.8)} \times 100\%$$

$$= 98.82\%$$

C. KLa CALCULATIONS

Calculations of KLa values are as follows:

$$KLa = \frac{(Q)(NTU)}{(A)(Co)(d)}$$

Where: Q = liquid flow rate in lb-moles/hour
= (27.8 lb-moles/hour-gpm)(gpm)

A = inner cross-sectional area of packing
= $5.84\ ft^2$

Co = molar density of water
= $3.47\ lb\text{-}moles/ft^3$

d = packing depth
= 0.853 ft

$$NTU = \frac{R}{R-1}\left[\ln\left[\frac{(Ci/Ce)(R-1)+1}{R}\right]\right]$$

= number of transfer units

First it is necessary to calculate NTU as follows:

R = (Hc)(G)/(Q)

Hc = Henry's Constant of contaminant in atmospheres

G = gas flow rate in lb-moles/hour
= (0.156)(cfm)

Q = liquid flow rate in lb-moles/hour
= (27.8)(gpm)

Use values from a benzene experiment:

cfm = 590 Therefore; G = (0.156)(590) = 92.0
gpm = 80 Therefore; Q = (27.8)(80) = 2224.0
Hc = 278 atmospheres
Ci = 8077.6 ug/L
Ce = 128.37 ug/L

Evaluating for R:

R = (278)(92.0)/(2224) = 11.5

Evaluating for NTU:

$$NTU = \frac{(11.5)}{(11.5 - 1)} \left[\ln \left[\frac{(8077.6)/(128.37)(11.5 - 1) + 1}{11.5} \right] \right] = 4.44$$

Evaluating for KLa:

$$\begin{aligned} KlA &= (2224.0)(4.44)/(5.843)(3.47)(0.853) \\ &= 571/\text{hours} \\ &= 9.5/\text{min} \end{aligned}$$

APPENDIX C

CONVERSION FACTORS

1 ft = 12 in
= 0.3048 M

1 yard = 3 ft

1 ft/s = 0.3048 M/s

1 cubic ft = 0.028317 cubic M

1 US gal = 231 cubic in
= 0.0037854 cubic M

1 L = 0.001 cubic M
= 0.035315 cubic ft

1 gal/min = 0.002228 cubic ft/s
= 0.06309 L/s

`C = 5/9(F - 32)

1 lbf = 4.448222 N

1 hp = 550(ft x lbf)/s
= 745.7 W

1 slug = 32.174 lb
= 14.594 kg

1 atm = 2116.2 lbf/square ft
= 14.696 lbf/square in
= 101,325 Pa

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APPENDIX D

DATA FILES

The following Appendix contains all raw and calculated data gathered and analyzed in the Rotary Air Stripper Evaluation.

RUN	LIQUID TEMP. °F	GAS FLOW (SCFM)	LIQUID FLOW (GPM)	GAS/LIQUID (CF/CF)
1	54	780	92	63.42
2	54	780	92	63.42
3	54	650	92	52.85
4	54	600	92	48.78
5	54	145	90	12.05
6	54	140	90	11.64
7	54	140	90	11.64
8	54	140	90	11.64
9	54	245	92	19.92
10	54	245	92	19.92
11	54	245	92	19.92
12	54	245	92	19.92
13	54	400	92	32.52
14	54	140	90	11.64
15	54	140	90	11.64
16	54	140	90	11.64
17	54	140	90	11.64
18	54	405	90	33.66
19	54	405	90	33.66
20	54	405	90	33.66
21	54	405	90	33.66
22	54	405	90	33.66
23	54	605	80	56.57
24	54	605	80	56.57
25	54	605	80	56.57
26	54	605	80	56.57
27	54	605	80	56.57
28	54	605	80	56.57
29	54	605	80	56.57
30	54	605	80	56.57
31	54	605	80	56.57
32	54	605	80	56.57
33	54	23	82	2.10
34	54	130	72	13.51
35	54	170	72	17.66
36	54	170	72	17.66
37	54	210	72	21.82
38	54	200	72	20.78
39	54	240	72	24.93
40	40	735	92	59.76
41	40	415	92	33.74
42	40	415	90	34.49
43	40	415	90	34.49
44	40	155	90	12.88
45	44	735	90	61.09
46	42	450	86	39.14
47	40	450	86	39.14

RUN	LIQUID TEMP. °F	GAS FLOW (SCFM)	LIQUID FLOW (GPM)	GAS/LIQUID (CF/CF)
48	40	450	84	40.07
49	40	200	84	17.81
50	40	730	88	62.05
51	40	590	88	50.15
52	40	590	87	50.73
53	40	590	86	51.32
54	40	150	85	13.20
56	52	730	86	63.49
57	52	590	85	51.92
58	52	590	84	52.54
59	52	590	84	52.54
60	52	150	82	13.68
61	52	800	82	72.98
62	54	800	84	71.24
63	54	730	83	65.79
64	54	590	82	53.82
65	54	590	80	55.17
66	54	590	80	55.17
67	54	1200	78	115.08
68	54	800	88	68.00
69	54	600	88	51.00
70	54	730	88	62.05
71	54	590	88	50.15
72	54	590	88	50.15
73	54	590	88	50.15
74	54	800	85	70.40
75	54	730	84	65.00
76	54	600	84	53.43
77	54	590	82	53.82
78	54	590	82	53.82
79	54	590	82	53.82
80	54	500	80	46.75
81	54	1600	82	145.95
82	54	730	82	66.59
83	54	600	81	55.41
84	54	590	81	54.48
85	54	590	80	55.17
86	54	590	80	55.17
87	54	400	80	37.40
88	54	1600	84	142.48
89	54	730	87	62.76
90	54	600	83	54.07
91	54	590	82	53.82
92	54	590	82	53.82
93	54	590	80	55.17
94	54	400	80	37.40
95	54	160	79	15.15

RUN	LIQUID TEMP. °F	GAS FLOW (SCFM)	LIQUID FLOW (GPM)	GAS/LIQUID (CF/CF)
96	54	600	79	56.81
97	54	730	79	69.12
98	54	590	79	55.86
99	54	590	79	55.86
100	54	590	79	55.86
101	54	400	79	37.87
102	54	1600	80	149.60
103	54	600	80	56.10
104	54	730	80	68.26
105	54	590	80	55.17
106	54	590	80	55.17
107	54	590	79	55.86
108	54	400	79	37.87
109	54	1600	78	153.44
110	54	600	78	57.54
111	54	730	78	70.01
112	54	590	78	56.58
113	54	590	78	56.58
114	54	590	77	57.31
115	54	400	77	38.86
116	54	1600	78	153.44
117	54	600	77	58.29
118	54	730	77	70.91
119	54	590	76	58.07
120	54	590	76	58.07
121	54	590	75	58.84
122	54	400	75	39.89
123	54	1600	77	155.43
124	54	600	76	59.05
125	54	730	76	71.85
126	54	590	75	58.84
127	54	590	75	58.84
128	54	590	75	58.84
129	54	400	74	40.43
130	54	1600	77	155.43
131	54	600	77	58.29
132	54	730	76	71.85
133	54	590	76	58.07
134	54	590	75	58.84
135	54	590	74	59.64
136	54	400	74	40.43
137	54	1600	76	157.47
138	54	699	75	69.71
139	54	730	75	72.81
140	54	590	75	58.84
141	54	590	74	59.64
142	54	590	73	60.45
143	54	400	72	41.56

RUN	LIQUID TEMP. °F	GAS FLOW (SCFM)	LIQUID FLOW (GPM)	GAS/LIQUID (CF/CF)
144	54	1600	70	170.97
145	54	600	70	64.11
146	54	730	70	78.01
147	54	590	70	63.05
148	54	590	70	63.05
149	54	590	70	63.05
150	54	400	69	43.36
151	54	1600	70	170.97
152	54	600	70	64.11
153	54	730	70	78.01
154	54	590	70	63.05
155	54	590	70	63.05
156	54	590	69	63.96
157	54	400	69	43.36
158	54	1600	70	170.97
159	54	600	70	64.11
160	54	730	70	78.01
161	54	590	69	63.96
162	54	590	69	63.96
163	54	590	68	64.90
164	54	400	68	44.00
165	54	1600	70	170.97
166	54	600	70	64.11
167	54	730	70	78.01
168	54	590	69	63.96
169	54	590	69	63.96
170	54	590	69	63.96
171	54	400	68	44.00
172	54	1200	119	75.43
173	54	800	118	50.71
174	54	600	118	38.03
175	54	400	117	25.57
176	54	1000	118	63.39
177	54	800	117	51.15
178	54	600	117	38.36
179	54	400	116	25.79
180	54	1000	115	65.04
181	54	800	114	52.49
182	54	600	114	39.37
183	54	400	114	26.25
184	54	1700	50	254.32
185	54	1000	50	149.60
186	54	1000	100	74.80
187	54	1700	100	127.16
188	54	600	50	89.76
189	54	400	50	59.84
190	54	600	100	44.88

RUN	LIQUID TEMP. F	GAS FLOW (SCFM)	LIQUID FLOW (GPM)	GAS/LIQUID (CF/CF)
191	54	400	100	29.92
192	54	1700	110	115.60
193	54	1700	110	115.60
194	54	850	110	57.80
195	54	1700	50	254.32
196	54	850	50	127.16
197	54	1200	110	81.60
198	54	800	110	54.40
199	54	600	110	40.80
200	54	400	110	27.20
201	54	1200	110	81.60
202	54	800	110	54.40
203	54	600	110	40.80
204	54	1200	100	89.76
205	54	800	100	59.84
206	54	600	100	44.88
207	54	1200	100	89.76
208	54	800	100	59.84
209	54	600	100	44.88

RUN	INVERTOR FREQUENCY	ROTOR VELOCITY (RPM)	ACCELERATION AT ROTOR EYE (M/SEC^2)
1	54	787.48	955.00
2	40	583.32	524.00
3	30	437.49	294.75
4	25	364.58	204.69
5	50	729.15	818.76
6	40	583.32	524.00
7	30	437.49	294.75
8	25	364.58	204.69
9	50	729.15	818.76
10	40	583.32	524.00
11	30	437.49	294.75
12	25	364.58	204.69
13	50	729.15	818.76
14	50.50	736.44	835.21
15	40	583.32	524.00
16	30	437.49	294.75
17	25	364.58	204.69
18	60	874.98	1179.01
19	50	729.15	818.76
20	40	583.32	524.00
21	30	437.49	294.75
22	25	364.58	204.69
23	60	874.98	1179.01
24	50	729.15	818.76
25	40	583.32	524.00
26	30	437.49	294.75
27	25	364.58	204.69
28	60	874.98	1179.01
29	50	729.15	818.76
30	40	583.32	524.00
31	30	437.49	294.75
32	25	364.58	204.69
33	11	157.50	38.20
34	60	874.98	1179.01
35	60	874.98	1179.01
36	50	729.15	818.76
37	50	729.15	818.76
38	40	583.32	524.00
39	40	583.32	524.00
40	40	583.32	524.00
41	40	583.32	524.00
42	30	437.49	294.75
43	25	364.58	204.69
44	25	364.58	204.69
45	40	583.32	524.00
46	40	583.32	524.00

RUN	INVERTOR FREQUENCY	ROTOR VELOCITY (RPM)	ACCELERATION AT ROTOR EYE (M/SEC^2)
47	30	437.49	294.75
48	25	364.58	204.69
49	25	364.58	204.69
50	40	584.78	526.63
51	40	584.78	526.63
52	35	510.41	401.19
53	30	437.49	294.75
54	25	364.58	204.69
56	40	583.32	524.00
57	40	583.32	524.00
58	35	510.41	401.19
59	30	437.49	294.75
60	25	364.58	204.69
61	50	729.15	818.76
62	50	729.15	818.76
63	40	583.32	524.00
64	40	583.32	524.00
65	35	510.41	401.19
66	30	437.49	294.75
67	50	730.61	822.03
68	50	729.15	818.76
69	55	802.07	990.69
70	40	583.32	524.00
71	40	583.32	524.00
72	35	510.41	401.19
73	30	437.49	294.75
74	50	729.15	818.76
75	40	583.32	524.00
76	55	802.07	990.69
77	40	583.32	524.00
78	35	510.41	401.19
79	30	437.49	294.75
80	30	437.49	294.75
81	55	802.07	990.69
82	40	583.32	524.00
83	55	802.07	990.69
84	40	583.32	524.00
85	35	510.41	401.19
86	30	437.49	294.75
87	30	437.49	294.75
88	55	802.07	990.69
89	40	583.32	524.00
90	55	802.07	990.69
91	40	583.32	524.00
92	35	510.41	401.19
93	30	437.49	294.75

RUN	INVERTOR FREQUENCY	ROTOR VELOCITY (RPM)	ACCELERATION AT ROTOR EYE (M/SEC^2)
94	30	437.49	294.75
95	55	802.07	990.69
96	55	802.07	990.69
97	40	583.32	524.00
98	40	583.32	524.00
99	35	510.41	401.19
100	30	437.49	294.75
101	30	437.49	294.75
102	55	802.07	990.69
103	55	802.07	990.69
104	40	583.32	524.00
105	40	583.32	524.00
106	35	510.41	401.19
107	30	437.49	294.75
108	30	437.49	294.75
109	55	802.07	990.69
110	55	802.07	990.69
111	40	583.32	524.00
112	40	583.32	524.00
113	35	510.41	401.19
114	30	437.49	294.75
115	30	437.49	294.75
116	55	802.07	990.69
117	55	802.07	990.69
118	40	583.32	524.00
119	40	583.32	524.00
120	35	510.41	401.19
121	30	437.49	294.75
122	30	437.49	294.75
123	55	802.07	990.69
124	55	802.07	990.69
125	40	583.32	524.00
126	40	583.32	524.00
127	35	510.41	401.19
128	30	437.49	294.75
129	30	437.49	294.75
130	55	802.07	990.69
131	55	802.07	990.69
132	40	583.32	524.00
133	40	583.32	524.00
134	35	510.41	401.19
135	30	437.49	294.75
136	30	437.49	294.75
137	55	802.07	990.69
138	55	802.07	990.69
139	40	583.32	524.00

RUN	INVERTOR FREQUENCY	ROTOR VELOCITY (RPM)	ACCELERATION AT ROTOR EYE (M/SEC^2)
140	40	583.32	524.00
141	35	510.41	401.19
142	30	437.49	294.75
143	30	437.49	294.75
144	55	802.07	990.69
145	55	802.07	990.69
146	40	583.32	524.00
147	40	583.32	524.00
148	35	510.41	401.19
149	30	437.49	294.75
150	30	437.49	294.75
151	55	802.07	990.69
152	55	802.07	990.69
153	40	583.32	524.00
154	40	583.32	524.00
155	35	510.41	401.19
156	30	437.49	294.75
157	30	437.49	294.75
158	55	802.07	990.69
159	55	802.07	990.69
160	40	583.32	524.00
161	40	583.32	524.00
162	35	510.41	401.19
163	30	437.49	294.75
164	30	437.49	294.75
165	55	802.07	990.69
166	55	802.07	990.69
167	40	583.32	524.00
168	40	583.32	524.00
169	35	510.41	401.19
170	30	437.49	294.75
171	30	437.49	294.75
172	40	583.32	524.00
173	40	583.32	524.00
174	40	583.32	524.00
175	40	583.32	524.00
176	45	656.24	663.19
177	45	656.24	663.19
178	45	656.24	663.19
179	45	656.24	663.19
180	55	802.07	990.69
181	55	802.07	990.69
182	55	802.07	990.69
183	55	802.07	990.69
184	55	802.07	990.69
185	55	802.07	990.69

RUN	INVERTOR FREQUENCY	ROTOR VELOCITY (RPM)	ACCELERATION AT ROTOR EYE (M/SEC^2)
186	55	802.07	990.69
187	55	802.07	990.69
188	55	802.07	990.69
189	55	802.07	990.69
190	55	802.07	990.69
191	55	802.07	990.69
192	55	802.07	990.69
193	40	583.32	524.00
194	40	583.32	524.00
195	55	802.07	990.69
196	55	802.07	990.69
197	50	729.15	818.76
198	50	729.15	818.76
199	50	729.15	818.76
200	50	729.15	818.76
201	55	802.07	990.69
202	55	802.07	990.69
203	55	802.07	990.69
204	40	583.32	524.00
205	40	583.32	524.00
206	40	583.32	524.00
207	55	802.07	990.69
208	55	802.07	990.69
209	55	802.07	990.69

RUN	INFLUENT BENZENE (ug/l)	INFLUENT TOLUENE (ug/l)	EFFLUENT BENZENE (ug/l)	EFFLUENT TOLUENE (ug/l)	% REM BENZENE	% REM TOLUENE
1	95.00	64.00	< .20	< 2.00	> 99.79	> 96.88
2	108.00	64.00	< .20	< 2.00	> 99.81	> 96.88
3	104.00	63.00	< 1.00	< 2.00	> 99.04	> 96.83
4	95.00	61.00	< 1.00	< 2.00	> 98.95	> 96.72
5	107.00	75.00	1.00	< 2.00	99.07	> 97.33
6	125.00	70.00	2.00	2.00	98.40	97.14
7	111.00	63.00	4.00	4.00	96.40	93.65
8	103.00	71.00	6.00	5.00	94.17	92.96
9	141.00	105.00	< 1.00	< 2.00	> 99.29	> 98.10
10	121.00	105.00	< 1.00	< 2.00	> 99.17	> 98.10
11	110.00	93.00	2.00	3.00	98.18	96.77
12	128.00	103.00	3.00	5.00	97.66	95.15
13	133.00	106.00	< 1.00	< 2.00	> 99.25	> 98.11
14	107.00	89.00	2.00	3.00	98.13	96.63
15	107.00	82.00	3.00	4.00	97.20	95.12
16	113.00	90.00	5.00	7.00	95.58	92.22
17	103.00	83.00	7.00	8.00	93.20	90.36
18	92.00	99.00	< .20	< 2.00	> 99.78	> 97.98
19	112.00	117.00	< .20	< 2.00	> 99.82	> 98.29
20	107.00	96.00	< .20	< 2.00	> 99.81	> 97.92
21	101.00	92.00	< 1.00	< 2.00	> 99.01	> 97.83
22	103.00	99.00	2.00	4.00	98.06	95.96
23	152.15	93.75	< .20	< 2.00	> 99.87	> 97.87
24	270.00	100.00	< .20	< 2.00	> 99.93	> 98.00
25	217.00	91.00	< .20	< 2.00	> 99.91	> 97.80
26	240.00	94.00	< .20	< 2.00	> 99.92	> 97.87
27	257.00	103.00	1.00	< 2.00	99.61	> 98.06
28	161.33	111.34	< .20	< .500	> 99.88	> 99.55
29	165.04	114.05	< .20	< .500	> 99.88	> 99.56
30	143.46	109.92	< .20	< .500	> 99.86	> 99.55
31	134.30	94.00	< 1.00	< 2.00	> 99.26	> 97.87
32	151.25	104.05	3.00	4.00	98.02	96.16
33	170.15	124.95	119.43	105.19	29.81	15.81
34	131.17	81.69	6.35	4.86	95.16	94.05
35	136.38	87.61	1.35	< 2.00	99.01	> 97.72
36	133.81	83.28	1.55	< 2.00	98.84	> 97.60
37	134.35	75.09	< 1.00	< 2.00	> 99.26	> 97.34
38	132.24	74.78	1.44	< 2.00	98.9[illegible]	> 97.33
39	129.42	73.30	< 1.00	< 2.00	> 99.23	> 97.27
40	167.79	.00	15.02	< .50	91.05	> N/A
41	170.23	.00	14.87	< .50	91.26	> N/A
42	173.71	.00	17.50	< .50	89.93	> N/A
43	182.31	.00	26.12	< .50	85.67	> N/A
44	174.58	.00	53.16	< .50	69.55	> N/A
45	108.15	.00	2.29	< .50	97.88	> N/A
46	113.31	.00	1.99	< .50	98.24	> N/A
47	104.54	.00	4.60	< .50	95.60	> N/A

RUN	INFLUENT BENZENE (ug/l)	EFFLUENT TOLUENE (ug/l)	INFLUENT BENZENE (ug/l)	EFFLUENT TOLUENE (ug/l)	% REM BENZENE	% REM TOLUENE
48	113.53	.00	12.40	< .50	89.08	> N/A
49	115.29	.00	42.20	< .50	63.40	> N/A
50	3223.10	.00	161.39	< .50	94.99	> N/A
51	3101.61	.00	151.65	< .50	95.11	> N/A
52	4055.98	.00	113.04	< .50	97.21	> N/A
53	3735.01	.00	173.08	< .50	95.37	> N/A
54	3633.69	.00	844.81	< .50	76.75	> N/A
56	3301.80	423.32	38.92	< .50	98.82	> 99.88
57	3696.70	486.30	38.42	< .50	98.96	> 99.90
58	3794.30	477.99	40.09	< .50	98.94	> 99.90
59	3651.30	459.52	57.01	< .50	98.44	> 99.89
60	3402.20	428.43	321.26	37.19	90.56	91.32
61	3798.90	476.43	25.88	< .50	99.32	> 99.90
62	8080.50	N/A	158.52	< .50	98.04	> N/A
63	8167.00	N/A	130.31	< .50	98.40	> N/A
64	8063.60	N/A	130.61	< .50	98.38	> N/A
65	8077.60	N/A	128.37	< .50	98.41	> N/A
66	8180.60	N/A	125.96	< .50	98.46	> N/A
67	8000.00	N/A	97.42	< .50	98.78	> N/A
68	116.42	399.17	< .20	< .50	> 99.83	> 99.87
69	118.75	403.78	< .20	< .50	> 99.83	> 99.88
70	119.83	423.32	< .20	< .50	> 99.83	> 99.88
71	112.60	406.41	< .20	< .50	> 99.82	> 99.88
72	114.90	401.19	< .20	< .50	> 99.83	> 99.88
73	123.82	425.94	< .20	3.07	> 99.84	99.28
74	142.17	1068.00	< .20	9.05	> 99.86	99.15
75	144.06	1125.00	< .20	8.78	> 99.86	99.22
76	149.33	1178.40	< .20	7.08	> 99.87	99.40
77	130.97	1181.10	< .20	7.91	> 99.85	99.33
78	132.38	1164.40	< .20	7.22	> 99.85	99.38
79	124.12	1103.00	< .20	11.46	> 99.84	98.96
80	123.52	1119.90	< .20	14.57	> 99.84	98.70
81	32.33	1589.30	< .20	50.59	> 99.38	96.82
82	152.33	6793.90	< .20	57.85	> 99.87	99.15
83	150.71	6583.90	< .20	56.68	> 99.87	99.14
84	126.70	5955.90	< .20	58.00	> 99.84	99.03
85	143.48	6178.40	< .20	62.36	> 99.86	98.99
86	140.79	6087.10	< .20	84.28	> 99.86	98.62
87	154.83	6241.20	< .20	101.99	> 99.87	98.37
88	118.84	17379.00	< .20	74.10	> 99.83	99.57
89	117.13	16114.00	< .20	91.06	> 99.83	99.43
90	121.96	16805.00	< .20	80.03	> 99.84	99.52
91	127.34	17068.00	< .20	113.22	> 99.84	99.34
92	127.51	17194.00	< .20	136.42	> 99.84	99.71
93	133.29	18014.00	< .20	225.52	> 99.85	98.75
94	131.70	19038.00	< .20	286.13	> 99.85	98.50
165	476.72	362.76	< 1.00	< .50	> 99.79	> 99.86

RUN	INFLUENT BENZENE (ug/l)	EFFLUENT TOLUENE (ug/l)	INFLUENT BENZENE (ug/l)	EFFLUENT TOLUENE (ug/l)	% REM BENZENE	% REM TOLUENE
166	505.68	366.59	< 1.00	< .50	> 99.80	> 99.86
167	509.10	375.66	< 1.00	< .50	> 99.80	> 99.87
168	511.56	368.90	< 1.00	< .50	> 99.80	> 99.86
169	533.38	374.83	< 1.00	< .50	> 99.81	> 99.87
170	507.75	342.95	1.18	< .50	99.77	> 99.85
171	553.91	366.30	1.84	< 2.00	99.67	> 99.45
172	1977.60	443.36	6.07	< .50	99.69	> 99.89
173	1893.70	484.37	7.73	< .50	99.59	> 99.90
174	1955.07	454.41	9.74	< .50	99.50	> 99.89
175	2161.10	492.85	16.23	2.86	99.25	99.42
176	2258.90	344.86	76.41	< .50	96.62	> 99.86
177	2768.80	362.22	63.29	< .50	97.71	> 99.86
178	2436.90	319.82	60.43	< .50	97.52	> 99.84
179	2717.10	353.69	66.62	< .50	97.55	> 99.86
180	2676.90	363.38	50.71	< .50	98.11	> 99.86
181	2717.20	311.68	48.83	< .50	98.20	> 99.84
182	2562.60	312.98	43.63	< .50	98.30	> 99.84
183	2978.00	383.93	42.33	< .50	98.58	> 99.87
184	4602.70	427.25	90.84	< .50	98.03	> 99.88
185	4719.70	418.47	103.43	< .50	97.81	> 99.88
186	4418.90	375.26	106.28	< .50	97.59	> 99.87
187	4610.50	404.39	89.74	< .50	98.05	> 99.88
188	4884.40	446.18	32.06	< .50	99.34	> 99.89
189	4712.80	351.36	33.56	< .50	99.29	> 99.86
190	4859.30	412.41	31.91	< .50	99.34	> 99.88
191	4976.70	435.41	28.63	< .50	99.42	> 99.89
192	4553.90	504.17	79.27	< .50	98.26	> 99.90
193	4434.50	397.88	60.65	< .50	98.63	> 99.87
194	4645.50	512.04	51.58	< .50	98.89	> 99.90
195	4330.50	371.48	42.57	< .50	99.02	> 99.87
196	4718.00	507.18	35.21	< .50	99.25	> 99.90
197	1680.00	552.45	1.83	< .50	99.89	> 99.91
198	1784.30	606.38	1.66	< .50	99.91	> 99.92
199	1537.50	447.97	1.83	< .50	99.88	> 99.89
200	1654.70	532.59	2.92	< .50	99.82	> 99.91
201	2333.20	684.43	19.58	< .50	99.16	> 99.93
202	2429.00	647.15	19.61	< .50	99.19	> 99.92
203	2462.30	657.71	16.64	< .50	99.32	> 99.92
204	4402.50	527.54	22.33	< .50	99.49	> 99.91
205	4158.70	488.06	21.51	< .50	99.48	> 99.90
206	4661.50	573.69	21.53	< .50	99.54	> 99.91
207	4640.50	570.06	14.95	< .50	99.68	> 99.91
208	4742.30	567.79	14.89	< .50	99.69	> 99.91
209	4572.20	535.38	13.92	< .50	99.70	> 99.91

RUN	INFLUENT TCE (ug/l)	EFFLUENT TCE (ug/l)	INFLUENT 1,2-DCE (ug/l)	EFFLUENT 1,2-DCE (ug/l)	% REMOVAL TCE	% REMOVAL 1,2-DCE
95	270.00	.88			99.67	
96	290.88	.59			99.80	
97	267.73	.59			99.78	
98	268.85	.22			99.92	
99	264.20	.44			99.83	
100	261.22	1.39			99.47	
101	290.70	.82			99.72	
102	897.21	.53			99.94	
103	743.31	.58			99.92	
104	798.23	.56			99.93	
105	835.71	.51			99.94	
106	970.53	.80			99.92	
107	691.91	1.88			99.73	
108	686.22	3.85			99.44	
109	2903.50	6.97			99.76	
110	2615.60	5.28			99.80	
111	2885.30	5.80			99.80	
112	2700.40	5.29			99.80	
113	2863.50	5.61			99.80	
114	2921.90	11.71			99.60	
115	2956.10	19.31			99.35	
116			258.28	1.80		99.30
117			236.84	26.26		88.91
118			310.13	20.62		93.35
119			315.08	39.90		87.34
120			284.33	43.66		84.64
121			353.47	59.74		83.10
122			357.50	93.47		73.85
123			1044.40	10		99.04
124			1031.50	62.62		93.93
125			1136	64		94.37
126			1014.70	95		90.64
127			986.91	106.26		89.23
128			1174.90	146.13		87.56
129			1105.30	226		79.55
130			2808.80	15.17		99.46
131			2968.50	229		92.29
132			3011.20	162.97		94.59
133			3037.30	284.13		90.65
134			3071.80	341.12		88.90
135			3039.90	431.41		85.81
136			3083.90	769.28		75.05
137	421.13	0			100	
138	439.94	0			100	
139	441.88	0			100	
140	437.69	0			100	
141	484.44	.29			99.94	

RUN	INFLUENT TCE (ug/1)	EFFLUENT TCE (ug/1)	INFLUENT 1,2-DCE (ug/1)	EFFLUENT 1,2-DCE (ug/1)	% REMOVAL TCE	% REMOVAL 1,2-DCE
142	509.96	.55			99.89	
143	265.53	1.01			99.62	
165	462.20	.86	702.39	4.08	99.81	99.42
166	813.08	.59	693.43	71.88	99.93	89.63
167	914.80	1.23	716.44	64.34	99.87	91.02
168	980.42	NA	751.26		NA	NA
169	1056.30	NA	769.45		NA	NA
170	1043.40	NA	743.95		NA	NA
171	1132.10	2.10	767.45	180.94	99.81	76.42
172	6079.14	11.84			99.81	
173	5447.80	13.67			99.75	
174	6279.30	16.27			99.74	
175	6328.20	19.11			99.70	

RUN	INFLUENT PCE (ug/l)	EFFLUENT PCE (ug/l)	% REMOVAL PCE
144	159.28	.24	99.85
145	163.52	NA	NA
146	163.76	.42	99.74
147	173.54	.28	99.84
148	181.75	.41	99.77
149	161.88	.57	99.65
150	163.63	.46	99.72
151	415.99	.65	99.84
152	170.75	.70	99.59
153	315.29	.66	99.79
154	305.56	.59	99.81
155	300.42	.66	99.78
156	354.39	.64	99.82
157	320.34	.66	99.79
158	537.96	3.80	99.29
159	726.26	3.87	99.47
160	741.19	2.20	99.70
161	751.66	2.91	99.61
162	796.94	2.57	99.68
163	804.01	2.77	99.66
164	752.99	3.32	99.56
165	621.99	1.11	99.82
166	1017.40	.72	99.93
167	1058.50	.75	99.93
168	1065	NA	NA
169	1066.90	NA	NA
170	1048.10	NA	NA
171	1090.90	1.57	99.86

RUN	GAS/LIQUID (CF/CF)	CHEMICAL COMPOUND	PERCENT REMOVAL	ROTOR VELOCITY (RPM)
1	63.42	BENZENE	99.79	787.48
2	63.42	BENZENE	99.81	583.32
3	52.85	BENZENE	99.04	437.49
4	48.78	BENZENE	98.95	364.58
5	12.05	BENZENE	99.07	729.15
6	11.64	BENZENE	98.40	583.32
7	11.64	BENZENE	96.40	437.49
8	11.64	BENZENE	94.17	364.58
9	19.92	BENZENE	99.29	729.15
10	19.92	BENZENE	99.17	583.32
11	19.92	BENZENE	98.18	437.49
12	19.92	BENZENE	97.66	364.58
13	32.52	BENZENE	99.25	729.15
14	11.64	BENZENE	98.13	736.44
15	11.64	BENZENE	97.20	583.32
16	11.64	BENZENE	95.58	437.49
17	11.64	BENZENE	93.20	364.58
18	33.66	BENZENE	99.78	874.98
19	33.66	BENZENE	99.82	729.15
20	33.66	BENZENE	99.81	583.32
21	33.66	BENZENE	99.01	437.49
22	33.66	BENZENE	98.06	364.58
23	56.57	BENZENE	99.87	874.98
24	56.57	BENZENE	99.93	729.15
25	56.57	BENZENE	99.91	583.32
26	56.57	BENZENE	99.92	437.49
27	56.57	BENZENE	99.61	364.58
28	56.57	BENZENE	99.88	874.98
29	56.57	BENZENE	99.88	729.15
30	56.57	BENZENE	99.86	583.32
31	56.57	BENZENE	99.26	437.49
32	56.57	BENZENE	98.02	364.58
1	63.42	TOLUENE	96.88	787.48
2	63.42	TOLUENE	96.88	583.32
3	52.85	TOLUENE	96.83	437.49
4	48.78	TOLUENE	96.72	364.58
5	12.05	TOLUENE	97.33	729.15
6	11.64	TOLUENE	97.14	583.32
7	11.64	TOLUENE	93.65	437.49
8	11.64	TOLUENE	92.96	364.58
9	19.92	TOLUENE	98.10	729.15
10	19.92	TOLUENE	98.10	583.32
11	19.92	TOLUENE	96.77	437.49
12	19.92	TOLUENE	95.15	364.58
13	32.52	TOLUENE	98.11	729.15
14	11.64	TOLUENE	96.63	736.44
15	11.64	TOLUENE	95.12	583.32

RUN	GAS/LIQUID (CF/CF)	CHEMICAL COMPOUND	PERCENT REMOVAL	ROTOR VELOCITY (RPM)
16	11.64	TOLUENE	92.22	437.49
17	11.64	TOLUENE	90.36	364.58
18	33.66	TOLUENE	97.98	874.98
19	33.66	TOLUENE	98.29	729.15
20	33.66	TOLUENE	97.92	583.32
21	33.66	TOLUENE	97.83	437.49
22	33.66	TOLUENE	95.96	364.58
23	56.57	TOLUENE	97.87	874.98
24	56.57	TOLUENE	98.00	729.15
25	56.57	TOLUENE	97.80	583.32
26	56.57	TOLUENE	97.87	437.49
27	56.57	TOLUENE	98.06	364.58
28	56.57	TOLUENE	99.55	874.98
29	56.57	TOLUENE	99.56	729.15
30	56.57	TOLUENE	99.55	583.32
31	56.57	TOLUENE	97.87	437.49
32	56.57	TOLUENE	96.16	364.58
95	15.15	TCE	99.67	802.07
96	56.81	TCE	99.80	802.07
97	69.12	TCE	99.78	583.32
98	55.86	TCE	99.92	583.32
99	55.86	TCE	99.83	510.41
100	55.86	TCE	99.47	437.49
101	37.87	TCE	99.72	437.49
102	149.60	TCE	99.94	802.07
103	56.10	TCE	99.92	802.07
104	68.26	TCE	99.93	583.32
105	55.17	TCE	99.94	583.32
106	55.17	TCE	99.92	510.41
107	55.86	TCE	99.73	437.49
108	37.87	TCE	99.44	437.49
109	153.44	TCE	99.76	802.07
110	57.54	TCE	99.80	802.07
111	70.01	TCE	99.80	583.32
112	56.58	TCE	99.80	583.32
113	56.58	TCE	99.80	510.41
114	57.31	TCE	99.60	437.49
115	38.86	TCE	99.35	437.49
117	58.29	1,2-DCE	88.91	802.07
118	70.91	1,2-DCE	93.35	583.32
119	58.07	1,2-DCE	87.34	583.32
120	58.07	1,2-DCE	84.64	510.41
121	58.84	1,2-DCE	83.10	437.49
122	39.89	1,2-DCE	73.85	437.49
123	155.43	1,2-DCE	99.04	802.07
124	59.05	1,2-DCE	93.93	802.07
125	71.85	1,2-DCE	94.37	583.32

RUN	GAS/LIQUID (CF/CF)	CHEMICAL COMPOUND	PERCENT REMOVAL	ROTOR VELOCITY (RPM)
126	58.84	1,2-DCE	90.64	583.32
127	58.84	1,2-DCE	89.23	510.41
128	58.84	1,2-DCE	87.56	437.49
129	40.43	1,2-DCE	79.55	437.49
130	155.43	1,2-DCE	99.46	802.07
131	58.29	1,2-DCE	92.29	802.07
132	71.85	1,2-DCE	75.05	583.32
133	58.07	1,2-DCE	90.65	583.32
134	58.84	1,2-DCE	88.90	510.41
135	59.64	1,2-DCE	85.81	437.49
136	40.43	1,2-DCE	75.05	437.49
144	170.97	PCE	99.85	802.07
145	64.11	PCE	NA	802.07
146	78.01	PCE	99.74	583.32
147	63.05	PCE	99.84	583.32
148	63.05	PCE	99.77	510.41
149	63.05	PCE	99.65	437.49
150	43.36	PCE	99.72	437.49
151	170.97	PCE	99.84	802.07
152	64.11	PCE	99.59	802.07
153	78.01	PCE	99.79	583.32
154	63.05	PCE	99.81	583.32
155	63.05	PCE	99.78	510.41
156	63.96	PCE	99.82	437.49
157	43.36	PCE	99.79	437.49
158	170.97	PCE	99.29	802.07
159	64.11	PCE	99.47	802.07
160	78.01	PCE	99.70	583.32
161	63.96	PCE	99.61	583.32
162	63.96	PCE	99.68	510.41
163	64.90	PCE	99.66	437.49
164	44.00	PCE	99.56	437.49
165	170.97	PCE	99.82	802.07
166	64.11	PCE	99.93	802.07
167	78.01	PCE	99.93	583.32
168	63.96	PCE	NA	583.32
169	63.96	PCE	NA	510.41
170	63.96	PCE	NA	437.49
171	44.00	PCE	99.86	437.49

RUN	CHEMICAL COMPOUND	INFLUENT CONC. (ug/l)	PERCENT REMOVAL	ROTOR VELOCITY (RPM)	GAS/LIQUID (CF/CF)
1	BENZENE	95.00	99.79	787.48	63.42
2	BENZENE	108.00	99.81	583.32	63.42
3	BENZENE	104.00	99.04	437.49	52.85
4	BENZENE	95.00	98.95	364.58	48.78
5	BENZENE	107.00	99.07	729.15	12.05
6	BENZENE	125.00	98.40	583.32	11.64
7	BENZENE	111.00	96.40	437.49	11.64
8	BENZENE	103.00	94.17	364.58	11.64
9	BENZENE	141.00	99.29	729.15	19.92
10	BENZENE	121.00	99.17	583.32	19.92
11	BENZENE	110.00	98.18	437.49	19.92
12	BENZENE	128.00	97.66	364.58	19.92
13	BENZENE	133.00	99.25	729.15	32.52
14	BENZENE	107.00	98.13	736.44	11.64
15	BENZENE	107.00	97.20	583.32	11.64
16	BENZENE	113.00	95.58	437.49	11.64
17	BENZENE	103.00	93.20	364.58	11.64
18	BENZENE	92.00	99.78	874.98	33.66
19	BENZENE	112.00	99.82	729.15	33.66
20	BENZENE	107.00	99.81	583.32	33.66
21	BENZENE	101.00	99.01	437.49	33.66
22	BENZENE	103.00	98.06	364.58	33.66
23	BENZENE	152.15	99.87	874.98	56.57
24	BENZENE	270.00	99.93	729.15	56.57
25	BENZENE	217.00	99.91	583.32	56.57
26	BENZENE	240.00	99.92	437.49	56.57
27	BENZENE	257.00	99.61	364.58	56.57
28	BENZENE	161.33	99.88	874.98	56.57
29	BENZENE	165.04	99.88	729.15	56.57
30	BENZENE	143.46	99.86	583.32	56.57
31	BENZENE	134.30	99.26	437.49	56.57
32	BENZENE	151.25	98.02	364.58	56.57
1	TOLUENE	64.00	96.88	787.48	63.42
2	TOLUENE	64.00	96.88	583.32	63.42
3	TOLUENE	63.00	96.83	437.49	52.85
4	TOLUENE	61.00	96.72	364.58	48.78
5	TOLUENE	75.00	97.33	729.15	12.05
6	TOLUENE	70.00	97.14	583.32	11.64
7	TOLUENE	63.00	93.65	437.49	11.64
8	TOLUENE	71.00	92.96	364.58	11.64
9	TOLUENE	105.00	98.10	729.15	19.92
10	TOLUENE	105.00	98.10	583.32	19.92
11	TOLUENE	93.00	96.77	437.49	19.92
12	TOLUENE	103.00	95.15	364.58	19.92
13	TOLUENE	106.00	98.11	729.15	32.52
14	TOLUENE	89.00	96.63	736.44	11.64
15	TOLUENE	82.00	95.12	583.32	11.64

RUN	CHEMICAL COMPOUND	INFLUENT CONC. (ug/l)	PERCENT REMOVAL	ROTOR VELOCITY (RPM)	GAS/LIQUID (CF/CF)
16	TOLUENE	90.00	92.22	437.49	11.64
17	TOLUENE	83.00	90.36	364.58	11.64
18	TOLUENE	99.00	97.98	874.98	33.66
19	TOLUENE	117.00	98.29	729.15	33.66
20	TOLUENE	96.00	97.92	583.32	33.66
21	TOLUENE	92.00	97.83	437.49	33.66
22	TOLUENE	99.00	95.96	364.58	33.66
23	TOLUENE	93.75	97.87	874.98	56.57
24	TOLUENE	100.00	98.00	729.15	56.57
25	TOLUENE	91.00	97.80	583.32	56.57
26	TOLUENE	94.00	97.87	437.49	56.57
27	TOLUENE	103.00	98.06	364.58	56.57
28	TOLUENE	111.34	99.55	874.98	56.57
29	TOLUENE	114.05	99.56	729.15	56.57
30	TOLUENE	109.92	99.55	583.32	56.57
31	TOLUENE	94.00	97.87	437.49	56.57
32	TOLUENE	104.05	96.16	364.58	56.57
95	TCE	270	99.67	802.07	15.15
96	TCE	290.88	99.80	802.07	56.81
97	TCE	267.73	99.78	583.32	69.12
98	TCE	268.85	99.92	583.32	55.86
99	TCE	264.20	99.83	510.41	55.86
100	TCE	261.22	99.47	437.49	55.86
101	TCE	290.70	99.72	437.49	37.87
102	TCE	897.21	99.94	802.07	149.60
103	TCE	743.31	99.92	802.07	56.10
104	TCE	798.23	99.93	583.32	68.26
105	TCE	835.71	99.94	583.32	55.17
106	TCE	970.53	99.92	510.41	55.17
107	TCE	691.91	99.73	437.49	55.86
108	TCE	686.22	99.44	437.49	37.87
109	TCE	2903.50	99.76	802.07	153.44
110	TCE	2615.60	99.80	802.07	57.54
111	TCE	2885.30	99.80	583.32	70.01
112	TCE	2700.40	99.80	583.32	56.58
113	TCE	2863.50	99.80	510.41	56.58
114	TCE	2921.90	99.60	437.49	57.31
115	TCE	2956.10	99.35	437.49	38.86
117	1,2-DCE	236.84	88.91	802.07	58.29
118	1,2-DCE	310.13	93.35	583.32	70.91
119	1,2-DCE	315.08	87.34	583.32	58.07
120	1,2-DCE	284.33	84.64	510.41	58.07
121	1,2-DCE	353.47	83.10	437.49	58.84
122	1,2-DCE	357.50	73.85	437.49	39.89
123	1,2-DCE	1044.40	99.04	802.07	155.43
124	1,2-DCE	1031.50	93.93	802.07	59.05
125	1,2-DCE	1136	94.37	583.32	71.85

RUN	CHEMICAL COMPOUND	INFLUENT CONC. (ug/l)	PERCENT REMOVAL	ROTOR VELOCITY (RPM)	GAS/LIQUID (CF/CF)
126	1,2-DCE	1014.70	90.64	583.32	58.84
127	1,2-DCE	986.91	89.23	510.41	58.84
128	1,2-DCE	1174.90	87.56	437.49	58.84
129	1,2-DCE	1105.30	79.55	437.49	40.43
130	1,2-DCE	2808.80	99.46	802.07	155.43
131	1,2-DCE	2968.50	92.29	802.07	58.29
132	1,2-DCE	3083.90	75.05	583.32	71.85
133	1,2-DCE	3037.30	90.65	583.32	58.07
134	1,2-DCE	3071.80	88.90	510.41	58.84
135	1,2-DCE	3039.90	85.81	437.49	59.64
136	1,2-DCE	3083.90	75.05	437.49	40.43
144	PCE	159.28	99.85	802.07	170.97
145	PCE	163.52	NA	802.07	64.11
146	PCE	163.76	99.74	583.32	78.01
147	PCE	173.54	99.84	583.32	63.05
148	PCE	181.75	99.77	510.41	63.05
149	PCE	161.88	99.65	437.49	63.05
150	PCE	163.63	99.72	437.49	43.36
151	PCE	415.99	99.84	802.07	170.97
152	PCE	170.75	99.59	802.07	64.11
153	PCE	315.29	99.79	583.32	78.01
154	PCE	305.56	99.81	583.32	63.05
155	PCE	300.42	99.78	510.41	63.05
156	PCE	354.39	99.82	437.49	63.96
157	PCE	320.34	99.79	437.49	43.36
158	PCE	537.96	99.29	802.07	170.97
159	PCE	726.26	99.47	802.07	64.11
160	PCE	741.19	99.70	583.32	78.01
161	PCE	751.66	99.61	583.32	63.96
162	PCE	796.94	99.68	510.41	63.96
163	PCE	804.01	99.66	437.49	64.90
164	PCE	752.99	99.56	437.49	44.00
165	PCE	621.99	99.82	802.07	170.97
166	PCE	1017.40	99.93	802.07	64.11
167	PCE	1058.50	99.93	583.32	78.01
168	PCE	1065.00	NA	583.32	63.96
169	PCE	1066.90	NA	510.41	63.96
170	PCE	1048.10	NA	437.49	63.96
171	PCE	1090.90	99.86	437.49	44.00

RUN	ROTOR VELOCITY (RPM)	PRESSURE DIFFERENTIAL (INCHES OF WATER)	GAS/LIQUID (CF/CF)
1	787.48	8.20	63.42
2	583.32	7.20	63.42
3	437.49	6.60	52.85
4	364.58	10.30	48.78
5	729.15	3.30	12.05
6	583.32	2.30	11.64
7	437.49	1.80	11.64
8	364.58	1.50	11.64
9	729.15	3.50	19.92
10	583.32	2.70	19.92
11	437.49	2.10	19.92
12	364.58	2.10	19.92
13	729.15	4.50	32.52
14	736.44	3.00	11.64
15	583.32	2.20	11.64
16	437.49	1.70	11.64
17	364.58	1.50	11.64
18	874.98	5.00	33.66
19	729.15	4.40	33.66
20	583.32	3.60	33.66
21	437.49	3.40	33.66
22	364.58	4.80	33.66
23	874.98	6.60	56.57
24	729.15	5.50	56.57
25	583.32	4.90	56.57
26	437.49	5.10	56.57
27	364.58	9.20	56.57
28	874.98	7.30	56.57
29	729.15	5.80	56.57
30	583.32	5.20	56.57
31	437.49	5.50	56.57
32	364.58	10.00	56.57
33	157.50	.40	2.10
34	874.98	3.90	13.51
35	874.98	4.30	17.66
36	729.15	3.70	17.66
37	729.15	3.90	21.82
38	583.32	3.00	20.78
39	583.32	3.30	24.93
40	583.32	7.00	59.76
41	583.32	4.00	33.74
42	437.49	4.10	34.49
43	364.58	7.60	34.49
44	364.58	2.00	12.88
45	583.32	5.70	61.09
46	583.32	4.40	39.14
47	437.49	4.40	39.14

RUN	ROTOR VELOCITY (RPM)	PRESSURE DIFFERENTIAL (INCHES OF WATER)	GAS/LIQUID (CF/CF)
48	364.58	3.50	40.07
49	364.58	1.30	17.81
50	584.78	6.80	62.05
51	584.78	5.50	50.15
52	510.41	5.50	50.73
53	437.49	6.10	51.32
54	364.58	1.80	13.20
56	583.32	6.90	63.49
57	583.32	5.50	51.92
58	510.41	5.50	52.54
59	437.49	6.10	52.54
60	364.58	1.90	13.68
61	729.15	8.00	72.98
62	729.15	8.00	71.24
63	583.32	6.80	65.79
64	583.32	5.50	53.82
65	510.41	5.50	55.17
66	437.49	6.30	55.17
67	730.61	10.80	115.08
68	729.15	8.70	68.00
69	802.07	6.90	51.00
70	583.32	7.10	62.05
71	583.32	6.30	50.15
72	510.41	6.00	50.15
73	437.49	6.90	50.15
74	729.15	8.60	70.40
75	583.32	6.70	65.00
76	802.07	7.00	53.43
77	583.32	6.00	53.82
78	510.41	5.50	53.82
79	437.49	6.10	53.82
80	437.49	4.30	46.75
81	802.07	15.60	145.95
82	583.32	6.70	66.59
83	802.07	6.00	55.41
84	583.32	5.90	54.48
85	510.41	5.70	55.17
86	437.49	5.90	55.17
87	437.49	4.40	37.40
88	802.07	14.50	142.48
89	583.32	6.70	62.76
90	802.07	6.10	54.07
91	583.32	5.80	53.82
92	510.41	5.60	53.82
93	437.49	6.00	55.17
94	437.49	4.30	37.40

RUN	ROTOR VELOCITY (RPM)	PRESSURE DIFFERENTIAL (INCHES OF WATER)	GAS/LIQUID (CF/CF)
95	802.07	13.80	15.15
96	802.07	6.70	56.81
97	583.32	6.70	69.12
98	583.32	5.70	55.86
99	510.41	5.40	55.86
100	437.49	5.80	55.86
101	437.49	4.40	37.87
102	802.07	15.60	149.60
103	802.07	7.00	56.10
104	583.32	6.80	68.26
105	583.32	5.60	55.17
106	510.41	5.40	55.17
107	437.49	5.60	55.86
108	437.49	4.10	37.87
109	802.07	15.80	153.44
110	802.07	6.90	57.54
111	583.32	6.80	70.01
112	583.32	5.60	56.58
113	510.41	5.40	56.58
114	437.49	5.60	57.31
115	437.49	4.00	38.86
116	802.07	13.20	153.44
117	802.07	6.90	58.29
118	583.32	6.40	70.91
119	583.32	5.60	58.07
120	510.41	5.40	58.07
121	437.49	5.70	58.84
122	437.49	4.30	39.89
123	802.07	13.20	155.43
124	802.07	7.10	59.05
125	583.32	6.80	71.85
126	583.32	5.70	58.84
127	510.41	5.40	58.84
128	437.49	5.70	58.84
129	437.49	4.10	40.43
130	802.07	14.10	155.43
131	802.07	6.80	58.29
132	583.32	6.70	71.85
133	583.32	5.70	58.07
134	510.41	5.50	58.84
135	437.49	5.70	59.64
136	437.49	4.30	40.43
137	802.07	13.10	157.47
138	802.07	6.90	69.71
139	583.32	6.70	72.81
140	583.32	5.70	58.84

RUN	ROTOR VELOCITY (RPM)	PRESSURE DIFFERENTIAL (INCHES OF WATER)	GAS/LIQUID (CF/CF)
141	510.41	5.30	59.64
142	437.49	5.60	60.45
143	437.49	4.30	41.56
144	802.07	12.50	170.97
145	802.07	7.10	64.11
146	583.32	6.60	78.01
147	583.32	5.50	63.05
148	510.41	5.30	63.05
149	437.49	5.40	63.05
150	437.49	4.10	43.36
151	802.07	12.70	170.97
152	802.07	6.90	64.11
153	583.32	6.60	78.01
154	583.32	5.60	63.05
155	510.41	5.40	63.05
156	437.49	5.60	63.96
157	437.49	4.20	43.36
158	802.07	15.40	170.97
159	802.07	7.00	64.11
160	583.32	6.60	78.01
161	583.32	5.60	63.96
162	510.41	5.40	63.96
163	437.49	5.60	64.90
164	437.49	4.20	44.00
165	802.07	12.80	170.97
166	802.07	7.00	64.11
167	583.32	6.80	78.01
168	583.32	5.60	63.96
169	510.41	5.40	63.96
170	437.49	5.60	63.96
171	437.49	4.10	44.00
172	583.32	14.70	75.43
173	583.32	9.50	50.71
174	583.32	7.50	38.03
175	583.32	5.70	25.57
176	656.24	12.10	63.39
177	656.24	9.90	51.15
178	656.24	7.60	38.36
179	656.24	6.20	25.79
180	802.07	12.90	65.04
181	802.07	11.60	52.49
182	802.07	7.00	39.37
183	802.07	8.30	26.25
184	802.07	10.60	254.32
185	802.07	7.50	149.60

RUN	ROTOR VELOCITY (RPM)	PRESSURE DIFFERENTIAL (INCHES OF WATER)	GAS/LIQUID (CF/CF)
186	802.07	11.80	74.80
187	802.07	19.50	127.16
188	802.07	5.20	89.76
189	802.07	4.30	59.84
190	802.07	8.10	44.88
191	802.07	6.50	29.92
192	802.07	20.90	115.60
193	583.32	16.20	115.60
194	583.32	8.40	57.80
195	802.07	13.30	254.32
196	802.07	8.00	127.16
197	729.15	12.00	81.60
198	729.15	9.60	54.40
199	729.15	8.40	40.80
200	729.15	6.80	27.20
201	802.07	12.00	81.60
202	802.07	9.80	54.40
203	802.07	8.50	40.80
204	583.32	10.40	89.76
205	583.32	7.20	59.84
206	583.32	7.00	44.88
207	802.07	10.80	89.76
208	802.07	8.40	59.84
209	802.07	8.00	44.88

RUN	GAS/LIQUID (CF/CF)	TOTAL POWER CONSUMP. (KW)	ROTOR VELOCITY (RPM)	% REM BENZENE
1	63.42	22.53	787.48	> 99.79
2	63.42	17.65	583.32	> 99.81
3	52.85	14.30	437.49	> 99.04
4	48.78	12.85	364.58	> 98.95
5	12.05	18.33	729.15	99.07
6	11.64	15.25	583.32	98.40
7	11.64	12.71	437.49	96.40
8	11.64	11.40	364.58	> 94.17
9	19.92	18.75	729.15	> 99.29
10	19.92	15.88	583.32	> 99.17
11	19.92	13.38	437.49	98.18
12	19.92	12.25	364.58	> 97.66
13	32.52	19.50	729.15	> 99.25
14	11.64	17.94	736.44	98.13
15	11.64	15.36	583.32	97.20
16	11.64	12.82	437.49	95.58
17	11.64	11.35	364.58	93.20
18	33.66	22.43	874.98	> 99.78
19	33.66	19.31	729.15	> 99.82
20	33.66	16.45	583.32	> 99.81
21	33.66	14.09	437.49	> 99.01
22	33.66	12.58	364.58	98.06
23	56.57	19.82	874.98	> 99.87
24	56.57	16.74	729.15	> 99.93
25	56.57	14.25	583.32	> 99.91
26	56.57	12.14	437.49	> 99.92
27	56.57	11.55	364.58	99.61
28	56.57	23.87	874.98	> 99.88
29	56.57	23.87	729.15	> 99.88
30	56.57	21.14	583.32	> 99.86
31	56.57	18.01	437.49	> 99.26
32	56.57	17.21	364.58	98.02
33	2.10	10.76	157.50	29.61
34	13.51	17.01	874.98	95.16
35	17.66	16.75	874.98	99.01
36	17.66	14.10	729.15	> 98.84
37	21.82	13.87	729.15	> 99.26
38	20.78	11.29	583.32	> 98.91
39	24.93	11.27	583.32	> 99.23
40	59.76	19.24	583.32	91.05
41	33.74	18.84	583.32	91.26
42	34.49	14.75	437.49	89.93
43	34.49	13.00	364.58	85.67
44	12.88	11.75	364.58	69.55
45	61.09	18.75	583.32	97.98
46	39.14	16.77	583.32	98.24

RUN	GAS/LIQUID (CF/CF)	TOTAL POWER CONSUMP. (KW)	ROTOR VELOCITY (RPM)	% REM BENZENE
47	39.14	14.24	437.49	95.60
48	40.07	12.90	364.58	89.08
49	17.81	12.08	364.58	63.40
50	62.05	18.42	584.78	94.99
51	50.15	17.83	584.78	95.11
52	50.73	16.36	510.41	97.21
53	51.32	14.97	437.49	95.37
54	13.20	11.98	364.58	76.75
56	63.49	18.16	583.32	98.82
57	51.92	17.21	583.32	98.96
58	52.54	15.81	510.41	98.94
59	52.54	14.63	437.49	98.44
60	13.68	11.75	364.58	90.56
61	72.98	20.42	729.15	99.32
62	71.24	20.85	729.15	98.04
63	65.79	17.39	583.32	98.40
64	53.82	17.00	583.32	98.38
65	55.17	15.47	510.41	98.41
66	55.17	14.30	437.49	98.46
67	115.08	21.04	730.61	> 98.78
68	68.00	21.98	729.15	> 99.83
69	51.00	22.84	802.07	> 99.83
70	62.05	18.43	583.32	> 99.83
71	50.15	17.84	583.32	> 99.82
72	50.15	16.40	510.41	> 99.83
73	50.15	15.10	437.49	> 99.84
74	70.40	20.85	729.15	> 99.86
75	65.00	17.52	583.32	> 99.86
76	53.43	21.42	802.07	> 99.87
77	53.82	17.06	583.32	> 99.85
78	53.82	15.64	510.41	> 99.85
79	53.82	14.48	437.49	> 99.84
80	46.75	13.77	437.49	> 99.84
81	145.95	24.98	802.07	> 99.38
82	66.59	17.39	583.32	> 99.87
83	55.41	21.29	802.07	> 99.87
84	54.48	16.91	583.32	> 99.94
85	55.17	15.48	510.41	> 99.86
86	55.17	14.32	437.49	> 99.86
87	37.40	13.77	437.49	> 99.87
88	142.48	25.14	802.07	> 99.83
89	62.76	17.45	583.32	> 99.83
90	54.07	21.37	802.07	> 99.84
91	53.82	17.00	583.32	> 99.84
92	53.82	15.64	510.41	> 99.84
93	55.17	14.30	437.49	> 99.85

RUN	GAS/LIQUID (CF/CF)	TOTAL POWER CONSUMP. (KW)	ROTOR VELOCITY (RPM)	% REM BENZENE
94	37.40	13.79	437.49	> 99.85
165	15.15	24.63	802.07	> 99.79
166	56.81	21.03	802.07	> 99.84
167	69.12	17.17	583.32	> 99.80
168	55.86	16.76	583.32	> 99.80
169	55.86	15.33	510.41	> 99.80
170	55.86	14.22	437.49	99.81
171	37.87	18.88	437.49	99.77
172	149.60	24.79	802.07	99.67
173	56.10	21.16	802.07	99.69
174	68.26	17.30	583.32	99.59
175	55.17	16.84	583.32	99.50
176	55.17	15.45	510.41	99.25
177	55.86	14.21	437.49	96.62
178	37.87	13.56	437.49	97.71
179	153.44	23.95	802.07	97.52
180	57.54	20.47	802.07	97.55
181	70.01	16.85	583.32	98.11
182	56.58	16.48	583.32	98.20
183	56.58	15.21	510.41	98.30
184	57.31	13.97	437.49	98.58
185	38.86	13.25	437.49	98.03
186	153.44	23.93	802.07	97.81
187	58.29	20.11	802.07	97.59
188	70.91	16.66	583.32	98.05
189	58.07	16.03	583.32	99.34
190	58.07	14.82	510.41	99.29
191	58.84	13.86	437.49	99.34
192	39.89	13.07	437.49	99.42
193	155.43	23.48	802.07	98.26
194	59.05	19.99	802.07	98.63
195	71.85	16.54	583.32	98.89
196	58.84	15.86	583.32	99.02
197	58.84	14.72	510.41	99.25
198	58.84	13.83	437.49	99.89
199	40.43	12.93	437.49	99.91
200	155.43	23.32	802.07	99.88

Run #	INVERTOR FREQUENCY	Q gpm	G SCFM	Ci in ug/l	Ce in ug/l	KLa in l/min	G/L (vol/vol)
33	11	82	23	170.15	119.43	1.35	2
8	25	90	140	103.00	6.00	9.65	12
17	25	90	140	103.00	7.00	9.04	12
7	30	90	140	111.00	4.00	11.56	12
16	30	90	140	113.00	5.00	10.74	12
6	40	90	140	125.00	2.00	14.83	12
15	40	90	140	107.00	3.00	12.57	12
14	50.50	90	140	107.00	2.00	14.20	12
5	50	90	145	107.00	1.00	16.71	12
44	25	90	155	174.58	53.16	3.42	12
54	25	85	150	3633.69	844.81	4.05	13
34	60	72	130	131.17	6.35	7.83	13
60	25	82	150	3402.20	321.26	6.69	14
36	50	72	170	133.81	1.55	10.98	14
35	60	72	170	136.38	1.35	11.40	18
49	25	84	200	115.29	42.20	2.52	18
12	25	92	245	128.00	3.00	11.32	18
11	30	92	245	110.00	2.00	12.14	20
10	40	92	245	121.00	1.00	14.69	20
9	50	92	245	141.00	1.00	15.19	20
38	40	72	200	132.24	1.44	10.69	20
37	50	72	210	134.35	1.00	11.51	21
39	40	72	240	129.42	1.00	11.11	[illegible]
175	40	117	400	2161.10	16.23	[illegible]	[illegible]
179	45	116	400	2717.10	66.62	[illegible]	[illegible]
183	55	114	400	2978.00	42.33	13.40	[illegible]
200	50	110	400	1654.70	2.92	15.16	[illegible]
191	55	100	400	4976.70	28.63	22.00	[illegible]
13	50	92	400	133.00	[illegible]	[illegible]	[illegible]
22	25	90	405	103.00	[illegible]	[illegible]	[illegible]
21	30	90	405	[illegible]	[illegible]	[illegible]	[illegible]
20	40	90	405	[illegible]	[illegible]	[illegible]	[illegible]
19	50	90	405	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	405	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
43	[illegible]	90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
42	30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	400	[illegible]	[illegible]	[illegible]	[illegible]
94	[illegible]	[illegible]	400	[illegible]	[illegible]	[illegible]	[illegible]
174	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
178	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Run #	INVERTOR FREQUENCY	Q gpm	G SCFM	Ci in ug/l	Ce in ug/l	KLa in 1/min	G/L (vol/vol)
80	30	80	500	123.52	.20	15.10	47
4	25	92	600	95.00	1.00	12.17	49
73	30	88	590	123.82	.20	16.50	50
72	35	88	590	114.90	.20	16.31	50
71	40	88	590	112.60	.20	16.26	50
51	40	88	590	3101.61	151.65	7.62	50
173	40	118	800	1893.70	7.73	18.87	51
52	35	87	590	4055.98	113.04	8.97	51
69	55	88	600	118.75	.20	16.37	51
177	45	117	800	2768.80	63.29	12.74	51
53	30	86	590	3735.01	173.08	7.57	51
57	40	85	590	3696.70	38.42	11.22	52
181	55	114	800	2717.20	48.83	13.20	52
59	30	84	590	3651.30	57.01	10.07	53
58	35	84	590	3794.30	40.09	11.04	53
3	30	92	650	104.00	1.00	12.34	53
76	55	84	600	149.33	.20	16.13	53
79	30	82	590	124.12	.20	15.29	54
78	35	82	590	132.38	.20	15.45	54
92	35	82	590	127.51	.20	15.36	54
64	40	82	590	8063.60	130.61	9.73	54
[illegible]	40	82	590	130.97	.20	15.42	54
[illegible]	40	82	590	127.34	.20	[illegible]	54
[illegible]	55	83	600	121.96	.20	[illegible]	54
[illegible]	50	110	800	1784.30	1.66	[illegible]	[illegible]
[illegible]	40	81	590	126.70	.20	[illegible]	54
[illegible]	30	80	590	8180.60	125.96	[illegible]	[illegible]
[illegible]	30	80	590	140.79	.20	[illegible]	[illegible]
[illegible]	30	80	590	133.29	.20	[illegible]	[illegible]
[illegible]	[illegible]	80	590	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	80	590	143.48	.20	[illegible]	[illegible]
[illegible]	[illegible]	81	600	[illegible]	.20	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Run #	INVERTOR FREQUENCY	Q gpm	G SCFM	Ci in ug/l	Ce in ug/l	KLa in l/min	G/L (vol/vol)
89	40	87	730	117.13	.20	15.89	63
176	45	118	1000	2258.90	76.41	11.33	63
2	40	92	780	108.00	.20	16.57	63
1	54	92	780	95.00	.20	16.23	63
56	40	86	730	3301.80	38.92	10.88	63
170	30	69	590	507.75	1.18	11.97	64
169	35	69	590	533.38	1.00	12.40	64
168	40	69	590	511.56	1.00	12.32	64
166	55	70	600	505.68	1.00	12.47	64
75	40	84	730	144.06	.20	15.81	65
180	55	115	1000	2676.90	50.71	12.95	65
63	40	83	730	8167.00	130.31	9.75	66
82	40	82	730	152.33	.20	15.54	67
68	50	88	800	116.42	.20	15.97	68
74	50	85	800	142.17	.20	15.88	70
62	50	84	800	8080.50	158.52	9.33	71
61	50	82	800	3798.90	25.88	11.58	73
186	55	100	1000	4418.90	106.28	10.49	75
172	40	119	1200	1977.60	6.07	19.49	75
167	40	70	730	509.10	1.00	12.33	78
197	50	110	1200	1680.00	1.83	21.18	82
188	55	50	600	4884.40	32.06	7.04	90
67	50	78	1200	8000.00	97.42	9.53	115
193	40	110	1700	4434.50	60.65	13.07	116
192	55	110	1700	4553.90	79.27	12.33	116
187	55	100	1700	4610.50	89.74	10.87	127
196	55	50	850	4718.00	35.21	6.77	127
68	55	84	1600	118.84	.20	14.80	142
61	55	82	1600	32.33	.20	11.48	146
185	55	50	1000	4719.70	103.43	5.25	150
165	55	70	1600	476.72	1.00	11.85	171
184	55	50	1700	4602.70	90.84	5.34	254
[illegible]	[illegible]	50	1700	4330.50	42.57	6.29	254

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